State of California
The Natural Resources Agency
DEPARTMENT OF WATER RESOURCES

South Delta Temporary Barriers Project

2008 South Delta Temporary Barriers Monitoring Report

July 2011

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Abbreviations and Acronyms

µg/L	micrograms per liter
µm	microgram
µS/cm	microsiemens per centimeter
DSM2	Delta Simulation Model II
af	acre-foot
ANOVA	analysis of variance
BO	biological opinion
CALFED	CALFED Bay-Delta Program
CCF	Clifton Court Forebay
CDEC	California Data Exchange Center
CDRR	combined differential recovery rates
cfs	cubic feet per second
cm	centimeters
CNFHC	California-Nevada Fish Health Center
CO_2	carbon dioxide
CRRL	Columbia River Research Laboratory
CVP	Central Valley Project
CWA	Clean Water Act
CWT	coded-wire tagged
Delta	Sacramento-San Joaquin River Delta
DFG	California Department of Fish and Game
DICU	Delta Island Consumptive Use
DO	dissolved oxygen
dpt	days post-transferred
DRRs	differential recovery rates
DWR	California Department of Water Resources
EIR/EIS	environmental impact report/environmental impact statement
EPA	US Environmental Protection Agency
FL	fork length
g	gram
g/dL	grams/deciliter
GIS	geographic information system
GLC barrier	Grant Line Canal barrier
HORB	Head of Old River barrier
HSD	Honestly Significant Difference
HTI	Hydroacoustic Technology Inc.
IEP	Interagency Ecological Program
IRIS	Integrated Risk Information System
L	liter
m^3	cubic meter
mg/L	milligrams per liter

mm	millimeters
mmol/L	millimoles/liter
MR barrier	Middle River barrier
MRH	Merced River Hatchery
MS-222	tricane methanesulfonate
MSL	mean sea level
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries	National Oceanic and Atmospheric Administration's National Marine Fisheries Service
NTU	nephelometric turbidity units
OCAP	operating criteria and plan
ORT barrier	Old River at Tracy barrier
PKD	proliferative kidney disease
RM	river mile
SJRA	San Joaquin River Agreement
SOP	standard operating procedure
State Water Board	State Water Resources Control Board
SWP	State Water Project
Tb	*T. bryosalmonae*
TBP	Temporary Barriers Project
TDS	total dissolved solids
TPS	Tom Paine Slough
USACE	US Army Corps of Engineers
USB	Universal Serial Bus
USBR	US Bureau of Reclamation
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VAMP	Vernalis Adaptive Management Plan
YSI	Yellow Spring Instrument

Chapter 1. Introduction

In 1990, the California Department of Water Resources (DWR) issued a draft environmental impact report/environmental impact statement (EIR/EIS) for the South Delta Water Management Program. The program's objectives are to:

1. Increase water levels, circulation patterns, and water quality in the southern Sacramento-San Joaquin River Delta area for local agricultural diversions.
2. Improve operational flexibility of the State Water Project (SWP) to help reduce fishery impacts and improve fishery conditions.

Because of concerns related to both agriculture and fisheries, the Temporary Barriers Project (TBP) was initiated to better determine the effects of installing permanent barriers in the south Delta. A 5-year program began in 1991 to test the proposed barriers. In 1996, this test was extended for another 5 years. In 2001, DWR received extensions from the US Army Corps of Engineers (USACE) to construct and operate the TBP from 2001 to 2007 and from 2008 through 2010. Because of varying hydrological conditions—and, accordingly, varying hydrodynamic patterns—as well as concerns for endangered species, the number of barriers installed and the installation schedules have been different each year of the program. The barrier installation and removal dates are based on a USACE Clean Water Act (CWA) Section 404 permit, a California Department of Fish and Game Streambed Alteration Agreement and various temporary entry permits from landowners and local reclamation districts. Table 1-1 shows installation and removal dates for the various years of the TBP.

Although the TBP has been in place since 1991, the Middle River barrier (MR barrier) and the fall Head of Old River barrier (HORB) have been installed in earlier years under different programs. The Grant Line Canal barrier (GLC barrier) was installed for the first time in 1996, at a site about 4.5 miles east of the location originally proposed. In 1997, the spring HORB was installed, with two 48-inch culverts. In 1998, none of the barriers was installed, because of high river flows throughout spring and summer. In 1999, the HORB was not installed in spring or fall, but the other barriers were installed. In 2000 through 2004 and 2007, all the barriers were installed (Table 1-1). In 2005 and 2006, the spring HORB was not installed, because of excessively high flows in the San Joaquin River, and in 2008 it was not installed in accordance with US District Court Judge Oliver Wanger's decision to protect Delta Smelt. The fall HORB was not installed in 2006 because of favorable dissolved oxygen (DO) conditions.

Subsequent to the 2001 project extension, DWR developed a new monitoring plan that specifically complies with the requirements of:

- DFG Incidental Take Permit No. 2081-2001-009-BD (issued April 4, 2001).
- DFG Streambed Alteration Agreement No. BD-2001-0001 (issued March 29, 2001).
- A biological opinion (BO) from the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (referred to as NOAA Fisheries) (issued April 5, 2001).
- The US Fish and Wildlife Service (USFWS) BO for the TBP from 2001 to 2007 (issued March 30, 2001).

This DWR monitoring plan consists of specific elements that are discussed in the following chapters. DWR participates in or funds these monitoring efforts. In some cases, funding may be augmented by Interagency Ecological Program (IEP) or CALFED Bay-Delta Program (CALFED) funds, or both. The elements of the monitoring plan, which covers salmon, steelhead, Delta smelt, and splittail, among other fish species, came from permit conditions required by DFG, NOAA Fisheries, and USFWS. Also included are terrestrial species, such as Swainson's hawks, pond turtles, and sensitive plants.

2008 Temporary Barriers Monitoring Report Contents

The chapters of this report are described below. Two chapters that were prepared by DFG for earlier years' editions of this report, "Fish Monitoring and Water Quality Analysis" and "Fish Entrainment Monitoring at the Head of Old River Barrier," are not included in this report. The chapter called "Fish Monitoring and Water Quality Analysis" was discontinued because of funding and staff shortages at DFG. The chapter called "Fish Entrainment Monitoring at the Head of Old River Barrier" was discontinued because the HORB (a rock barrier) was not installed in 2008 in accordance with a decision by US District Court Judge Oliver Wanger to protect Delta smelt.

Chapter 2 — Salmon Smolt Survival Investigations (Prepared by Patricia Brandes, USFWS)

This chapter[1] describes the methods used in conducting the 2008 Vernalis Adaptive Management Plan (VAMP) Chinook salmon smolt survival investigations. It presents results of the calculated survival indices and absolute survival estimates for juvenile Chinook salmon during the VAMP 2008 test period.

Chapter 3 — Barrier Effects on State Water Project and Central Valley Project Entrainment (Prepared by Katherine Marquez, DWR)

This chapter investigates the potential effect of the TBP on fish entrainment at the Skinner fish facility (an SWP facility) and Tracy fish facility (a Central Valley Project [CVP] facility). Daily salvage densities for 2008 are analyzed and compared with TBP operations, Delta hydrodynamics, and project export flows.

Chapter 4 — Swainson's Hawk Survey and Monitoring, 2008 Construction Season (Prepared by Mike Bradbury, DWR)

This chapter describes Swainson's hawk observations and the effects of the barriers' construction activities in 2008 on nesting pairs within a 0.5-mile radius of the sites.

Chapter 5 — Water Elevations (Prepared by Mike Abiouli, DWR)

This chapter presents results of the monitoring conducted in 2008 to determine the effects of the barriers on water surface elevations and circulation patterns in the southern Delta channels.

Chapter 6 — South Delta Water Quality (Prepared by Dave Bosworth, DWR)

Monitoring was conducted in 2008 to evaluate the changes in various water quality parameters, such as water temperature, DO levels, specific electrical conductivity, and turbidity, due to installation and operation of the barriers. It also describes results from water samples that were sent to an analytical laboratory for analysis of dissolved ammonia, dissolved nitrite and nitrate, dissolved organic nitrogen, dissolved orthophosphate, chlorophyll *a*, and pheophytin *a*.

Chapter 7 — Hydrodynamic Modeling (Prepared by Bob Suits, DWR)

This chapter describes DWR's Delta Simulation Model II, DSM2 (Hydro module), which was used to conduct a hydrodynamic simulation of the effects the temporary barriers have on water levels in the south Delta for the year 2008. In this chapter, the DSM2-simulated stages and flows are compared with historical data in the south Delta.

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[1] This chapter is a republication of Chapter 5, Salmon Smolt Survival Investigations, in *2008 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*, prepared by the San Joaquin River Group Authority for the California Water Resources Control Board in compliance with D-1641 in January 2009.

Table 1-1. Schedule of installation and removal dates for south Delta temporary barriers from 1987 through 2008 (11x17 large format. See separate PDF online.

Middle River

Year	Installation Started	Installation Closed	Installation Completed	Notched	Removal Started	Removal Breached	Removal Completed
1987			15-May		End of Sep		End of Sep
1988	26-May		28-May		23-Sep		23-Sep
1989			12-Apr		26-Sep		26-Sep
1990			16-Apr		29-Sep		29-Sep
1991	4-Apr		5-Apr		27-Sep		27-Sep
1992	8-Apr		10-Apr		28-Sep		29-Sep
1993	14-Jun		17-Jun		23-Sep		24-Sep
1994	23-Apr		25-Apr		29-Sep		5-Oct
1995	9-Aug		11-Aug		10-Oct		10-Oct
1996	18-May		20-May		29-Sep		29-Sep
1997	3-Apr		7-Apr		27-Sep		28-Sep
1998	(vii)						
1999	15-May		18-May		29-Sep		2-Oct
2000	4-Apr		6-Apr		1-Oct		7-Oct
2001	20-Apr		23-Apr		12-Nov	13-Nov	17-Nov
2002	10-Apr		15-Apr		20-Nov	20-Nov	23-Nov
2003	12-Apr	15-Apr	23-Apr	17-Sept.	7-Nov	8-Nov	10-Nov
2004	9-Apr	12-Apr	13-Apr	23-Sept.	9-Nov.	10-Nov.	12-Nov
2005	10-May	12-May	17-May	15-Sept.	7-Nov	8-Nov	9-Nov.
2006	5-Jul	7-Jul	8-Jul	1-Oct	17-Nov	18-Nov	20-Nov
2007	7-Apr	10-Apr	10-Apr	21-Sept.	19-Nov	20-Nov	29-Nov
2008	19-May	21-May	23-May	10-Sept.	5-Nov	5-Nov	9-Nov.

Old River near Tracy (ORT)

Year	Installation Started	Installation Closed	Installation Completed	Notched	Removal Started	Removal Breached	Removal Completed
1987							
1988							
1989							
1990							
1991	14-Aug		30-Aug		28-Sep		13-Oct. (i)
1992	15-April boat port on		01-May 09-May boat port on		30-Sep		Oct-09(ii)
1993	12-May		1-Jun		27-Sep		6-Oct
1994	22-April boat port on. All culverts tied open (5/18 to 6/1)		24-April 01-May		26-Sep		10-Oct
1995	3-Aug		8-Aug		27-Sep		6-Oct
1996	12-May		10-Jun (iii)		29-Sep		16-Oct
1997	8-Apr		17-Apr		30-Sep		7-Oct
1998	(vii)						
1999	15-May		28-May		28-Sep		8-Oct
2000	4-Apr		16-Apr		1-Oct		7-Oct
2001	23-Apr		26-Apr		13-Nov	14-Nov	26-Nov
2002	1-Apr		18-Apr		16-Nov	16-Nov	29-Nov
2003	1-Apr	14-Apr	22-Apr	17-Sept.	13-Nov	15-Nov	25-Nov
2004	1-Apr	15-Apr	20-Apr	10-Sept.	8-Nov.	8-Nov.	1-Dec.
2005	9-May	31-May	6-Jun	15-Sept.	8-Nov.	10-Nov	30-Nov
2006	7-Jul	17-Jul	31-Jul	1-Oct	13-Nov	16-Nov	8-Dec
2007	2-Apr	18-Apr	23-Apr	21-Sep	5-Nov	7-Nov	18-Nov
2008	12-May	4-Jun	19-Jun	10-Sept.	3-Nov	4-Nov	25-Nov

Grant Line Canal

Year	Installation Started	Installation Closed	Installation Completed	Flashboards Adjusted	Removal Started	Removal Breached	Removal Completed
1987							
1988							
1989							
1990							
1991							
1992							
1993							
1994							
1995							
1996	17-Jun		10-Jul		2-Oct		15-Oct
1997	21-May		4-Jun		26-Sep		15-Oct
1998	(vii)						
1999	15-May		3-Jun		23-Sep		5-Oct
2000	19-May		1-Jun		1-Oct		7-Oct
2001	2-May		9-May		11-Nov	12-Nov	18-Nov
2002	1-Apr		12-Jun		14-Nov	16-Nov	25-Nov
2003	1-Apr. (Partial) 9-June (Complete)	11-Jun	23-Apr. (Partial) 17-June (Complete)	16-Sept.	10-Nov	12-Nov	25-Nov
2004	1-Apr. (Partial) 2-June (Complete)	9-Apr (partial) 5-June (complete)	28-Apr (partial) 9-June (complete)	9-Sept.	11-Nov	12-Nov	6-Dec
2005	2-May	14-Jul	18-Jul	14-July & 14-Sept.	7-Nov	15-Nov	30-Nov
2006	7-Jul	20-Jul	26-Jul	20-Jul & 1-Oct	14_nov	21-Nov	6-Dec
2007	9-Apr (Partial) 27-Apr (Completed)	17-Apr (Partial) 10-May (Completed)	17-Apr (Partial) 11-May (Completed)	17-Apr (Partial) 10-May (Completed)	6-Nov	8-Nov	29-Nov
2008	19-May (Partial) 23-May (Full)	2-June (Partial) 26-June (Full)	2-June (Partial) 27-June (Full)	10-Sept.	8-Nov	11-Nov	24-Nov

Spring Head of Old River

Year	Installation Started	Installation Closed	Installation Completed	Removal Started	Removal Breached	Removal Completed
1987						
1988						
1989						
1990						
1991						
1992	15-April boat port on		23-April @ 4ft 26-April@6ft 01-May	2-Jun		9-Jun
1993						
1994	21-April boat port on		23-April @ 10ft 01-May	18-May		20-May
1995	(vii)					
1996	6-May		11-May	16-May		3-Sept (iv)
1997	9-Apr		16-Apr	15-May		19-May (viii)
1998	(vii)					
1999	(vii)					
2000	5-Apr		16-Apr	19-May		2-Jun
2001	17-Apr		26-Apr	23-May		30-May
2002	2-Apr		18-Apr	22-May	24-May	7-Jun
2003	1-Apr	15-Apr	21-Apr	16-May	18-May	3-Jun
2004	1-Apr	15-Apr	21-Apr	19-May	24-May	10-Jun
2005	(vii)	(vii)	(vii)	(vii)	(vii)	(vii)
2006	(vii)	(vii)	(vii)	(vii)	(vii)	(vii)
2007	11-Apr	20-Apr	26-Apr	19-May	22-May	6-Jun
2008	x	x	x	x	x	x

Fall Head of Old River (v)

Year	Installation Started	Installation Closed	Installation Completed	Notched	Removal Started	Removal Breached	Removal Completed
1987	9-Sep		11-Sep				28-Nov
1988	22-Sep		28-Sep				2-Dec
1989	27-Sep		28-Sep		27-Nov		30-Nov
1990	10-Sep		11-Sep				27-Nov
1991	9-Sep		13-Sep		22-Nov		27-Nov
1992	8-Sep		11-Sep		30-Nov		4-Dec
1993	8-Nov (vii)		11-Nov		3-Dec		7-Dec
1994	6-Sep		8-Sep		28-Nov		30-Nov
1995	(vii)						
1996	30-Sep		3-Oct		18-Nov		22-Nov
1997							
1998	(vii)						
1999	(viii)						
2000	27-Sep		7-Oct		27-Nov		8-Dec
2001	24-Sep		6-Oct		22-Nov	22-Nov	2-Dec
2002	24-Sep		4-Oct		11-Nov	12-Nov	21-Nov
2003	2-Sept.	15-Sept.	18-Sep	16-Sept.	3-Nov	4-Nov	13-Nov
2004	7-Sep	27-Sept.	29-Sept.	28-Sept.	1-Nov.	2-Nov.	12-Nov
2005	19-Sept.	28-Sept.	30-Sept.	29-Sep	7-Nov	8-Nov	15-Nov
2006	(ix)	(ix)	(ix)	(ix)	(ix)	(ix)	(ix)
2007	5-Oct	17-Oct	18-Oct	18-Oct	9-Nov	10-Nov	29-Nov
2008	1-Oct	16-Oct	16-Oct	16-Oct	3-Nov	3-Nov	9-Nov

(i) Barrier notched on Sept. 28, 1991. Construction resumed on Oct. 10 and finished on Oct. 13.
(ii) Barrier notched on Sept. 30, 1992. Construction resumed on Oct. 2 and finished on Oct. 9.
(iii) Construction was delayed on May 17 and resumed on June 5 due to high flows.
(iv) Barrier was breached on May 16 on an emergency basis, but complete removal wasn't done until Sept. 3, after USACE demanded permit compliance of complete removal.
(v) Barrier was installed in previous years.
(vi) Installation delayed due to high flows.
(vii) Not installed due to high San Joaquin River flows.
(viii) Not installed upon DFG's request.
(ix) Not installed because existing flows and dissolved oxygen levels in the San Joaquin River were sufficient for Chinook salmon.
(x) Not installed in accordance with Wanger decision to protect Delta smelt.

Chapter 2. Salmon Smolt Survival Investigations[1]

The biological investigations associated with the 2008 VAMP study have transitioned away from the use of coded-wire tagged (CWT) salmon and toward acoustic telemetry methodologies. The lack of study fish from Merced River Hatchery (MRH), starting in 2007, has prompted this transition. Trawling associated with the recapture of the CWT outmigrants at Chipps Island has been reduced to decrease catches of Delta smelt. This reduction in sampling would have resulted in fewer recoveries of the CWT fish even if study fish had been available. Compared with traditional mark-recapture techniques, acoustic telemetry provides greater temporal and spatial coverage of the outmigration process. Further, continuous, simultaneous monitoring at several locations allows the estimation of distribution probabilities at junctions and reach-specific survival throughout the study region. Moreover, acoustic telemetry data are amenable to a suite of robust and well-developed statistical approaches that allow for quantification of the uncertainty associated with estimates of survival, detection, and distribution probabilities.

Introduction

During the 2008 study, Chinook salmon smolts were acoustically tagged with Hydroacoustic Technology Inc. (HTI) tags and released at 2 locations (Durham Ferry and Stockton) in the San Joaquin River. Releases were made on April 29 (Durham Ferry), May 1 (Stockton), May 6 (Durham Ferry), and May 8 (Stockton). Each release was divided in half, with half released during the day and the other half released at night. Releases at Stockton occurred during the day and at night on the slack tide following the flood or ebb tides. This design facilitated easier transportation and was intended to obtain an “average” survival rate for juvenile salmon migrating through the Delta. Because there could be a difference in survival for groups released during the day rather than at night, the study needed to get an estimate of survival that incorporated both conditions. At Stockton where the tide is variable, releases were made on the slack tides during the day and at night to obtain estimates of survival that incorporated the varying tidal cycles as well as the diurnal differences.

Each tagged fish was detected and uniquely identified as it passed acoustic receivers placed at various locations throughout the Delta. Detection data from monitoring sites will be analyzed within a release-recapture model to simultaneously estimate survival, route distribution, and detection probabilities throughout the Delta.

Unfortunately, the transmitters used in this study were fundamentally flawed. Transmitters exhibited inaccurate coding and premature failure. The former substantially increased data processing time, and the latter has likely biased estimates of survival and travel times (see Appendix A, section A3) by violating the most basic assumption of mark-recapture models: Marks (i.e., transmitters) function properly throughout the duration of the study. In lieu of the results, this chapter will present the survival model and its capabilities and limitations based on the conceptual model shown in Figure 2-11, which forms the basis of survival and distribution probabilities for juvenile Chinook salmon outmigrants during the VAMP studies.

[1] This chapter is a republication of Chapter 5, Salmon Smolt Survival Investigations, in *2008 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*, prepared by the San Joaquin River Group Authority for the California Water Resources Control Board in compliance with D-1641 in January 2009.

Transmitter Implantation and Fish Holding

Tagging operations occurred at MRH during the weeks of April 28 and May 5, 2008. Food was withheld from study fish for 24 to 36 hours prior to transmitter implantation. During each week of tagging, fish were surgically implanted with HTI acoustic transmitters following procedures defined by Adams et al. (1998) and Martinelli et al. (1998). The HTI Model 795 S micro acoustic tag used for this study weighed 0.65 grams (g) in air, was 16.4 millimeters (mm) long, with a diameter of 6.7 mm. A minimum fish size of 12 g was used, which translated into a 5.4% transmitter-to-body weight ratio.

On the first day of each tagging week, fish were implanted with tags to be released at Durham Ferry. On the third day of each tagging week, fish were implanted with tags to be released at Stockton. Fish were transported to release sites on the second and fourth days of each tagging week. For each release site and release date, there were 2 separate release times and therefore 2 separate transportation efforts (Table 2-1). Tagging efforts and fish holding were organized to maintain clear separation of these subgroups.

In order to evaluate the effects of tagging, transportation, and release, several groups of fish were implanted with inactive, or dummy, transmitters. For each release effort (day and night) at each release site, 10 fish implanted with dummy transmitters were included (Table 2-1) in the tagging process. To monitor for potential disease progression in study fish, an additional 40 fish were tagged and transferred to the USFWS' California-Nevada Fish Health Center (CNFHC) at Coleman National Fish Hatchery. Fish in all dummy-tagged groups were subjected to identical tagging procedures as the study fish, and they were interspersed randomly into the tagging order for each release group.

Tagging procedures were based on a standard operating procedure (SOP) developed by the Columbia River Research Laboratory (CRRL). The SOP directed all aspects of the tagging operation, and several quality assurance checks were made during each tagging session to ensure compliance with the SOP guidance. Prior to transmitter implantation, fish were anesthetized in 70 milligrams per liter (mg/L) tricane methanesulfonate (MS-222) buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia and were measured (fork length [FL] to the nearest mm) and weighed (to the nearest 0.1 g). Following implantation procedures outlined in Adams et al. (1998) and Martinelli et al. (1998), fish were surgically implanted with acoustic transmitters. Typical surgery times were less than three minutes. Then, fish were placed into perforated 19-liter (L) holding containers with high DO concentrations (110% to 130%) to recover from anesthesia effects. Holding containers were perforated, starting 15 centimeters (cm) from the bottom, to allow water exchange. The non-perforated section of the container held 7 L of water to allow transfer without complete dewatering. Each holding container was stocked with 3 tagged fish and was covered with a snap-on lid. Holding containers were held in shaded, labeled tanks with flowing water for approximately 24 hours after tagging. Water levels were adjusted in holding tanks to ensure that tagged fish had access to air to be able to adjust their buoyancy to compensate for the weight of the transmitter. All release groups were held in separate tanks.

Table 2-1. Tag and release dates by groups

		Tag date (2008)	Release date (2008)	Release time	Number					
					Tagged	Transported	Mortalities	Released[a]	Non-functional tags	Effective release[b]
Week 1 experimental groups	DF1A	Apr 28	Apr 29	1720 (day)	144	144	0	144	16	128
	DF1B	Apr 28	Apr 29	2225 (night)	141	139	1	138	20	118
	ST1A	Apr 30	May 1	1455 (day)	95	93	0	93	4[c]	89
	ST1B	Apr 30	May 1	2212 (night)	95	95	1	94	17	77
Week 1 experimental total					475	471	2	469	57	428
Week 1 dummy-tagged groups	DF1A-Dummy	Apr 28	N/A	N/A	10	10	N/A	N/A	N/A	N/A
	DF1B-Dummy	Apr 28	N/A	N/A	10	10	N/A	N/A	N/A	N/A
	ST1A-Dummy	Apr 30	N/A	N/A	10	10	N/A	N/A	N/A	N/A
	ST1B-Dummy	Apr 30	N/A	N/A	10	10	N/A	N/A	N/A	N/A
	Coleman-Dummy	Apr 30	N/A	N/A	40	N/A	N/A	N/A	N/A	N/A
Week 1 dummy total					80					

		Tag date (2008)	Release date (2008)	Release time	Number					
					Tagged	Transported	Mortalities	Released[a]	Non-functional tags	Effective release[b]
Week 2 experimental groups	DF2A	May 5	May 6	1635 (day)	140	140	1	139	7	132
	DF2B	May 5	May 6	2200 (night)	144	144	0	144	10	134
	ST2A	May 7	May 8	1657 (day)	85	85	0	85	13	72
	ST2B	May 7	May 8	2217 (night)	78	78	0	78	3	75
Week 2 experimental total					447	447	1	446	33	413
Dummy-tagged groups	DF2A-Dummy	May 5	May 6	N/A	10	10	N/A	N/A	N/A	N/A
	DF2B-Dummy	May 5	May 6	N/A	10	10	N/A	N/A	N/A	N/A
	ST2A-Dummy	May 7	May 8	N/A	10	10	N/A	N/A	N/A	N/A
	ST2B-Dummy	May 7	May 8	N/A	10	10	N/A	N/A	N/A	N/A
Week 2 dummy total					40					

[a] The number released with functioning transmitters may differ from the number released due to a number of defective tags (Appendix A, section A3).

[b] Two non-functional tags from ST1A were held at MRH and not transported or released. These are not included in the “Non-functional tags” column.

[c] Non-functional tags represent tags that were not heard during the 24-hour holding period after tagging.

During the 24-hour recovery period, tagged fish were monitored by a series of hydrophones installed in the holding tanks. This monitoring period allowed the operational status of each transmitter to be confirmed prior to transportation to release sites.

Transportation to Release Sites

In order to minimize fish transfers and the associated stress to fish, specially designed transport tanks were used to move fish from MRH to the release sites. The tanks were designed to securely hold a series of 19-L perforated buckets filled with fish. Tanks had an internal frame that held 20–25 buckets in individual compartments to minimize contact between containers and to prevent tipping. Insulation was added to the exterior of the metal tanks to reduce water temperature fluctuations. Two transport tanks were positioned on a flatbed trailer equipped to deliver oxygen during transport. Salt was added to the transport tanks based on standard procedures used by the hatchery.

Immediately prior to loading, all containers were visually inspected for fish mortalities or signs of poor recovery (e.g., erratic swimming behavior). Holding containers were removed from holding tanks and loaded into the transport tanks. Thermographs positioned in each holding tank were transferred to the transport tank to record the full water temperature history for a given release group.

Water Temperature Monitoring

Water temperature at the hatchery was monitored with recording thermographs in the source tank and holding tanks. Individually numbered thermographs were initially deployed in the single source tank from which all fish were taken for tagging. When tagging was completed, the appropriate thermograph was transferred from the source tank to the holding tank that contained the corresponding batch of study fish. During this transfer, the thermograph was held out of the water long enough to ensure that a temperature spike was recorded.

Fish Acclimation Prior to Release

After the study fish were tagged at MRH, held for approximately 24 hours, and transported to the release site, they were acclimated to differences in water temperatures between the transport truck and those in the river at the release site prior to release. Introducing fish to broad changes in water temperature with no tempering period can create stress and thermal shock. To reduce the likelihood of behavioral changes or physiological shock associated with transferring study fish from the transport tanks to the river, and to document the temperature and DO conditions experienced by the fish from the source tank to the holding pools, during transport, and at the release sites, acclimation guidelines were developed for the releases in 2008.

Temperature and DO were measured and recorded at the MRH loading site, at the MRH entrance nearest the public road, midway during the transport trip, and at the release site. Thermographs were placed into transport tanks to record water temperatures during transport. Water temperatures in the transport tanks at MRH prior to transporting the fish to the release sites ranged between 11 °C and 15 °C. Over the course of the 2.5-hour to 3-hour drive from MRH to the release sites, the water temperatures increased in the transport tanks to between 12.8 °C and 17.9 °C. Water temperature in the river at the time of the releases ranged between 17.7 °C and 20.3°C.

Two unanticipated problems occurred for the first daytime release at Durham Ferry on April 29 that resulted in deviations from the guidelines developed for acclimating and releasing the fish at the release sites: an inability to obtain water from the hatchery truck at Durham Ferry due to the low-pressure head between the hatchery truck and the pools; and a lack of commitment from the farmer at the release site to keep his agricultural pump off for several hours after each release was made.

The guidelines for acclimating the fish from the water temperature in the transport tanks to that of the river was to place the buckets containing the fish into pools containing hatchery water and to increase the water temperature by adding river water to the pools over the course of an hour. Once the water temperature had reached that of the river, the fish were to be held for an additional hour prior to release.

The inability to replace the river water holding the pools rigid with cooler water from the transport truck for the first Durham Ferry release resulted in higher water temperatures in the pools (21.2 °C) than in the river (17.2 °C) due to solar radiation prior to loading the buckets into the pools. Once the buckets were placed in the pools, the water temperature in the pools decreased. Water temperature in the river subsequently increased to 19.1 °C by the time the fish were released, approximately 3 hours later.

Water quality in the pools was maintained during the holding period through continuous exchange of water between the river and the pools, using pumps.

As in past years, the local farmer had been asked to turn off his adjacent agricultural pump near Durham Ferry so that fish could be released without being exposed to the potential mortality associated with entrainment. Once at the release site, it appeared there was no guarantee that the pump would be shut off long enough for the first release or that it would be shut off for all following releases scheduled at Durham Ferry. Thus, to ensure that the fish released did not experience mortality or differential mortality associated with the operation of the agricultural pump, a boat was obtained to ferry the buckets of fish downstream before releasing them. This change to the protocol increased the tempering/holding time of the first Durham Ferry group to around 3 hours and 10 minutes, with an additional 20–25 minutes to make the 3 to 5 trips downstream to release all of the fish. Immediately prior to release, each bucket was checked for any dead or impaired fish. All fish were alive at the time of release at approximately 1700.

For the night release at Durham Ferry on April 29, the water temperature in the pools that had originated from the river was identical to that of the river. To make the night release more comparable to the day release, the water in the pools was not tempered. The fish were held in the pools for 3 hours to obtain a similar holding period to the fish released during the day. The night release was made at approximately 2200, using the ferrying method. One fish was observed to be dead just prior to the night release.

For both Durham Ferry releases on May 6, 200-gallon tubs (instead of small swimming pools) were filled with river water prior to loading the buckets into the tubs. Shade structures were used to prevent the temperature of the river water from increasing once it was in the tubs. Once buckets were loaded into the tubs, the tempering was completed over 2 hours. Fish in buckets were ferried by boat on multiple trips to the release site. Releases were completed by 1635 and 2200. No dead fish were observed in either of the Durham Ferry releases made on May 6.

For the day and night releases at Stockton on May 1 and May 8, the 200-gallon tubs were filled with hatchery water from the transport truck prior to putting the buckets into the tubs (Figure 2-1). Once the buckets containing the fish were placed in the tubs, river water was put into the tubs until the temperature reached equilibrium, about one-and-a-half hours. Fish were held for another 30 to 45 minutes and then loaded into a boat and transported by boat to the release site (10 minutes). Two boat trips were made for each of the Stockton releases on each day: 2 for the day releases and 2 for the night releases.

The tagged fish were released by boat on the San Joaquin River about 300 yards downstream of Durham Ferry (river mile [RM] 69.5) and near Stockton, downstream of Buckley Cove (RM 37) at Windmill Cove in the middle of the main channel (RM 35.5).

Figure 2-1. Buckets in acclimation tubs at Stockton

Dummy-Tagged Fish

Dummy-tagged fish were put into net pens at the release sites just after the release of the other tagged fish. A total of 80 dummy-tagged fish were held in the net pens to assess the direct effect of tagging and transport processes on the mortality of test fish. Twenty fish, implanted with dummy tags, were held at each of the release sites (Durham Ferry and Stockton) each week. Each of the day and night releases had 10 dummy-tagged fish transported with the functionally tagged groups. Dummy-tagged fish were held in net pens (volume ~ 1 cubic meter [m^3]; mesh size ~ 3 mm) at each release location for 48 hours. After 48 hours, each of the dummy-tagged fish was examined for mortality and condition. Dummy tags used during the first release period were reused during the second week of tagging.

Fish were examined for swimming vigor first and then were euthanized for measuring and documenting their general condition. Each fish was measured (FL to the nearest 1 mm) and examined qualitatively in the field for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration. Any mortality was documented, as well (Table 2-2).

Table 2-2. Characteristics assessed for Chinook salmon smolt condition and short-term survival

Character	Normal	Abnormal
Percent scale loss	Lower relative numbers based on 0 to 100%	Higher relative numbers based on 0 to 100%
Body color	High-contrast dark dorsal surface and light sides	Low-contrast dorsal surfaces and sides, coppery color
Fin hemorrhaging	No bleeding at base of fins	Blood present at base of fins
Eyes	Normally shaped	Bulging or with hemorrhaging
Gill color	Dark beet-red- to cherry-red-colored gill filaments	Gray- to light-red-colored gill filaments
Vigor	Active swimming (prior to anesthesia)	Lethargic or motionless (prior to anesthesia)

Five of the 79 fish with dummy tags recovered from the net pens after 48 hours were dead (6%). One fish from the April 29 night release at Durham Ferry was not in the net pen after the 48-hour holding period (Table 2-3). Three of the 5 dead fish were from the Durham Ferry release on May 6 (2 from the day release and 1 from the night release). The others were from the Stockton release made on May 8 (day release) and the Durham Ferry (night release) made on April 29. Mean FL size ranged from 105 mm to 112 mm for all of the groups (Table 2-3). Mean scale loss was 6% or less, all had normal body color, 3 had fin hemorrhaging, one had bulging eyes, and five had poor gill color (Table 2-3).

Short-term survival was 94% within the net pens. Those that were found alive were swimming vigorously and were generally in good condition. These data indicate that the fish used for the VAMP in 2008 were in generally good condition; however, some mortality was observed. It interesting to note that the April 29 group released at Durham Ferry during the day did not appear to have any negative effects from being put into pools that had higher water temperatures than the river. It is possible that the mortality of the fish in the other groups was associated with being tagged.

Release Groups

The total number of fish tagged and released for the experiment was to be 950, or 475 per release period. Within each release period, approximately 285 fish (or 60%) were to be released at Durham Ferry and 190 (40%) were to be released at Stockton. The actual number released with functioning tags was less, due to tag failure and some mortality during transport.

Because the proportion of fish allocated to each release site directly influences the sample size—and, accordingly, the precision of estimates lower in the system—simulated data were used to explore the relationship between the proportion of tags allocated to each site and the precision of parameter estimates. These data were used to select the optimal allocation to each site. Given 2 release periods (separated by 1 week) at each site, both full and reduced models were used with a “predicted” data set to estimate the precision about each parameter with a range of tag allocations. As expected with a fixed number of tags available for each release period (n = 475), allocating more tags to a given release site under the full model increased the precision of estimates based solely on fish released at that site but decreased the precision of estimates based on fish released at the other site (Figure 2-2). The intersection of the 2 lines represents the allocation that provides the highest precision for both release groups given the specific input parameters in the model (in this case, the “predicted” scenario). However, the relationship between allocation (i.e., the sample size) and precision is nonlinear; “flatter” segments of the curve may be considered more stable. Thus, the optimal tag allocation, based on both intersection (to maximize precision for both releases) and stability (to minimize risk) was selected. Visual assessment of “precision versus allocation” curves for all parameters under the “predicted” scenario suggested that the optimal tag allocation would be 60 percent (n = 285) to Durham Ferry and 40 percent (n = 190) to Stockton, respectively.

Table 2-3. **Results of dummy-tagged fish evaluated after being held 48 hours at the release sites as part of VAMP 2008**

Release site, release date (2008) — day or night	Examination date (2008), time	Mean (sd) fork length (mm)	Mortality	Mean (sd) scale loss	Normal body color	Fin hemorrhaging	Normal eye quality	Normal gill color
Durham Ferry, Apr 29 — day	May 1, 1715	111 (6)	0/10	4 (2)	10/10	10/10	10/10	10/10
Durham Ferry, Apr 29 — night	May 1, 2200	112 (4)	1/9	3 (1)	8/8	8/8	7/8	8/8
Stockton, May 1 — day	May 3, 1500	107 (2)	0/10	6 (3)	10/10	8/10	10/10	10/10
Stockton, May 1 — night	May 3, 2200	112 (8)	0/10	3 (1)	10/10	10/10	10/10	10/10
Durham Ferry, May 6 — day	May 8, 1613	105 (2)	2/10	6 (4)	8/8	8/8	8/8	4/8
Durham Ferry, May 6 — night	May 8, 2040	109 (2)	1/10	3 (1)	9/9	9/9	9/9	9/9
Stockton, May 8 — day	May 10, 1700	110 (4)	1/10	4 (2)	9/9	9/9	9/9	9/9
Stockton, May 8 — night	May 10, 2215	110 (5)	0/10	3 (2)	10/10	9/10	10/10	9/10

Another simulation was conducted to investigate how using 50 fish (15 to each Durham Ferry release; 10 to each Stockton release) in the experiment instead of in a tag life study would increase the precision of parameter estimates. The full and reduced models were run under the “predicted” scenario, where 300 and 200 tagged smolts (compared with 285 and 190) are released at Durham Ferry and Stockton, respectively. Incorporating these extra tags caused the standard error for each parameter to increase by no more than 0.004 and 0.002 under the full and reduced models, respectively. Given the value of tag life data and the minimal increase in precision associated with allocating an additional 50 fish to the experimental releases, it was concluded that these tags were most valuable when allocated to a tag life study.

Fish Monitoring

Receiver Locations

The hydrophone receiver network shown in Figure 2-3 was developed as part of a series of collaborative and collegial VAMP biology group meetings involving San Joaquin River Agreement (SJRA) partners along with agency (NOAA, the US Environmental Protection Agency [EPA], the US Geological Survey (USGS), etc.) and stakeholder input. Throughout these discussions, a hierarchy of study objectives was discussed in relation to the tradeoffs associated with a variety of different hydrophone placement scenarios. Principal objectives of the proposed hydrophone layout are to estimate overall survival to Chipps Island; and to compare overall survival in the main stem San Joaquin River to survival in the central Delta, which is potentially a function of San Joaquin River flows and export rates.

Receivers at Chipps Island and Jersey Point were difficult to deploy because of the large channel width at those locations. Multiport hydrophones (with 4 ports) were placed across the channel to ensure detection of the acoustically tagged fish as they passed these locations. At Chipps Island, Jersey Point, and Three-Mile Slough, independent dual arrays were deployed so that survival to those locations could be estimated.

In addition, acoustic receivers were located upstream (north) and downstream (south) of the Stockton wastewater treatment plant—the sites are identified as STP(n) and STP(s), respectively—to estimate mortality that occurred between the 2 receivers. During the 2007 experiment, 116 of 800 tags released were found “not moving” near the wastewater treatment plant.

Receiver Monitoring

Personnel from DFG, the USFWS Stockton office, DWR, and the US Bureau of Reclamation (USBR) maintained a total of 20 receivers. The receivers were monitored once per week from April 28 through May 28. At each site, the receiver strongbox was opened, and the battery was removed and replaced with a fully charged battery. The Universal Serial Bus (USB) flash drives with the acoustic monitoring data on them were replaced with empty flash drives each week. Used batteries were recharged for use the following week. USGS maintained the multiport receivers at Jersey Point and Chipps Island (MAL).

Eleven sites required use of a boat operator and crew to change the batteries and retrieve the data. Sites that were maintained using a boat were Three Mile Slough (the sites in Figure 2-3 identified as TMS, north and south), False River (identified as FAL), North Old River (identified as OSJ), Stockton wastewater treatment facility (identified as STPn and STPs), Channel Markers 16 and 18 (identified as SJT), Middle River (identified as MR), and Turner Cut (identified as TRN, north and south). (Also see Figure 2-4.)

Temperature Monitoring

Water temperature was monitored during the VAMP 2008 study using individual computerized temperature recorders (e.g., HOBO U22 Water Temp Pro v2, manufactured by Onset Computer Corp.). Water temperatures were measured at locations along the longitudinal gradient of the San Joaquin River and interior Delta channels between Durham Ferry and Chipps Island—locations along the migratory pathway for the juvenile Chinook salmon released as part of these tests (Appendix A, section A1). As part of the 2008 VAMP monitoring program, additional temperature recorders were deployed in the south and central Delta (Appendix A, section A1) to provide geographic coverage for characterizing water temperature conditions while juvenile salmon emigrated from the lower San Joaquin River through the Delta. Water temperature was recorded at 24-minute intervals throughout the period of the VAMP 2008 investigations. Water temperatures also were recorded within the hatchery raceways at MRH coincident with the period when juvenile Chinook salmon were being tagged and held.

Figure 2-2. Relation between tag allocation (proportion of total, n = 500, tags allocated to Durham Ferry) and predicted precision (standard error), for S6 under the full model; "predicted" scenario

(The solid line represents estimates based solely on fish released at Durham Ferry; the dashed line represents estimates based solely on fish released at Stockton.)

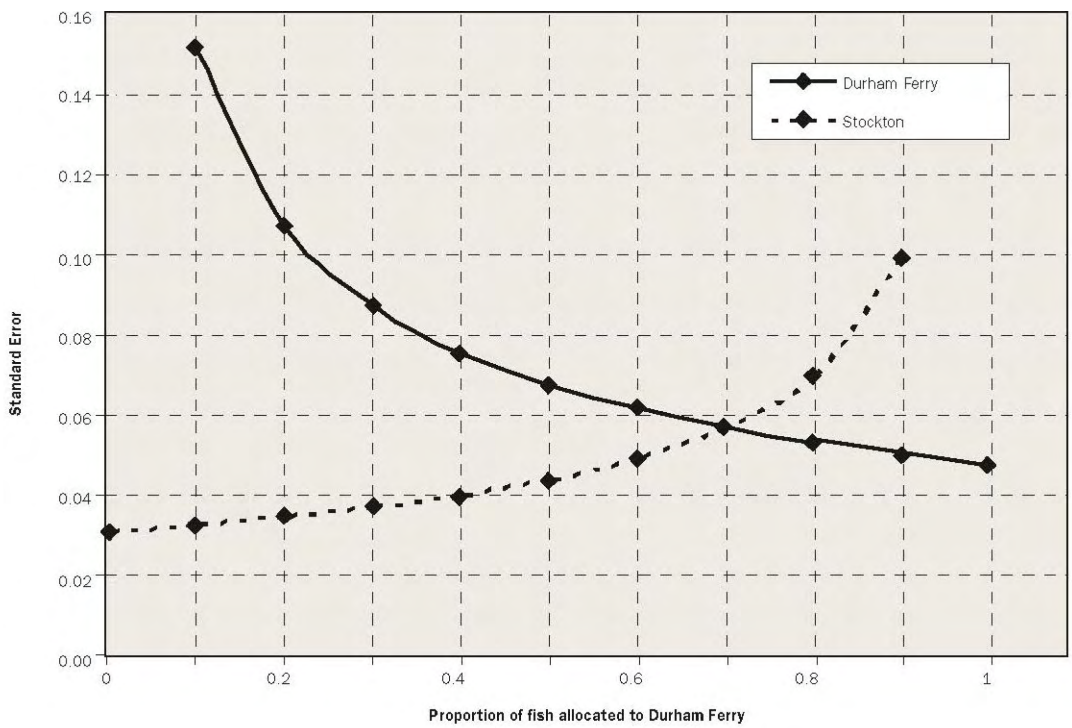


Figure 2-3. Map of primary (red) and secondary (yellow) priority acoustic monitoring sites, with number of independent arrays in parentheses

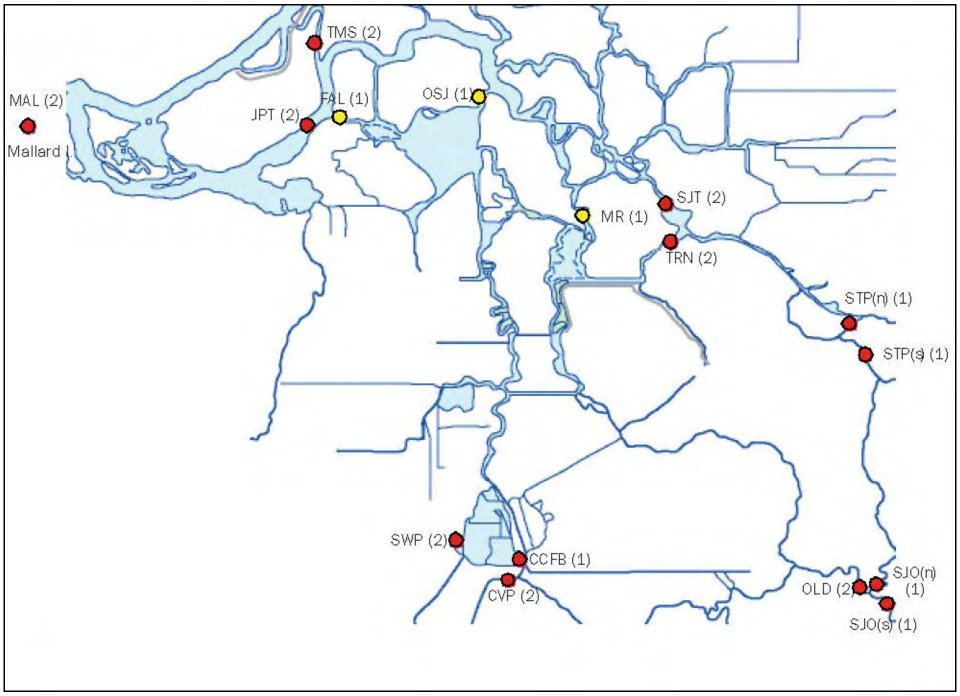


Figure 2-4. Battery maintenance being performed at San Joaquin River, Channel Marker 16

Results of water temperature monitoring within MRH showed that juvenile Chinook salmon were reared in, and acclimated to, water temperatures of approximately 11 °C to 17 °C (52 °F to 63 °F) prior to release into the lower San Joaquin River (Appendix A, section A2). Results of water temperature monitoring at Durham Ferry, Stockton (confluence), and Chipps Island during the April-May fall-run Chinook salmon smolt emigration from the San Joaquin River through the Delta are shown in Figures 2-5, 2-6, and 2-7. Water temperature monitoring showed that water temperatures throughout the lower San Joaquin River and Delta (Appendix A, section A2) were higher than those at the hatchery during the spring months, which is consistent with results of temperature monitoring in all previous years of the VAMP tests. Water temperatures measured within the lower San Joaquin River and Delta (Figures 2-5, 2-6, and 2-7 and Appendix A, section A2) were within a range considered to be suitable (typically lower than 20 °C [68 °F]) during April and the majority of May in the main stem San Joaquin River (e.g., Durham Ferry, Stockton, and Chipps Island, and at other monitoring locations [Appendix A, section A2]) but exceeded 20 °C (68 °F) in the lower San Joaquin River in late May (Appendix A, section A2). Water temperatures within the lower San Joaquin River showed a typical seasonal pattern of increasing temperature during the spring months. Results of the 2008 water temperature monitoring, in contrast to results from previous years, showed that water temperatures in the lower river were similar to water temperatures observed farther downstream during April and were lower at Chipps Island in late May (Figure 2-7) when compared with temperatures farther upstream (Figures 2-5 and 2-6). Water temperatures measured in the river during April–May would not be expected to result in adverse effects or reduced survival of emigrating juvenile Chinook salmon released as part of the VAMP 2008 investigations. Water temperatures measured downstream within the Delta during April and early May were within the general range considered to be suitable for juvenile fall-run Chinook salmon migration.

Evaluation for Delayed Mortality and Saltwater Survival — Effects of Proliferative Kidney Disease

Introduction

Proliferative kidney disease (PKD) has been diagnosed in MRH juvenile Chinook salmon for several decades (Hedrick et al. 1986). This trout and salmon disease is caused by the myxosporean parasite of freshwater bryozoans, *T. bryosalmonae* (Tb) (Canning et al. 2002). The progressive kidney inflammation and associated hypoplastic anemia is likely to reduce the fitness and performance of affected fish (Clifton-Hadley et al. 1987). Nichols and Foott (2002) reported Tb infections in natural juvenile Chinook salmon collected in the Merced River and Tuolumne River. The bryozoan *Fredericella* is reported as a host for Tb and was observed at the water intakes of MRH (Okamura and Wood 2002). Okamura and Wood speculate that salmonids may be an accidental host for this bryozoan parasite, given the strong inflammatory response characterized by PKD and the observation that infections can occur from water supplies without fish. The incidence of Tb infection in MRH salmon inspected prior to and shortly after release has ranged from 4% to 100% (Harmon et al. 2004). The vast majority of these infections have been deemed early, and the fish were asymptomatic. In 2005, the performance of MRH Chinook was tracked in swim and saltwater challenges through mid-June (Foott et al. 2007).

The objective of the study in 2008 was to follow the health status and saltwater adaptation performance of Tb-infected MRH juvenile Chinook salmon used for the VAMP outmigrant salmon study. These fish were reared at temperatures similar to those of the San Joaquin River at the CNFHC wet laboratory for a period of time that encompassed the outmigration of the VAMP study population.

Figure 2-5. Water temperatures at Durham Ferry during April–May 2008

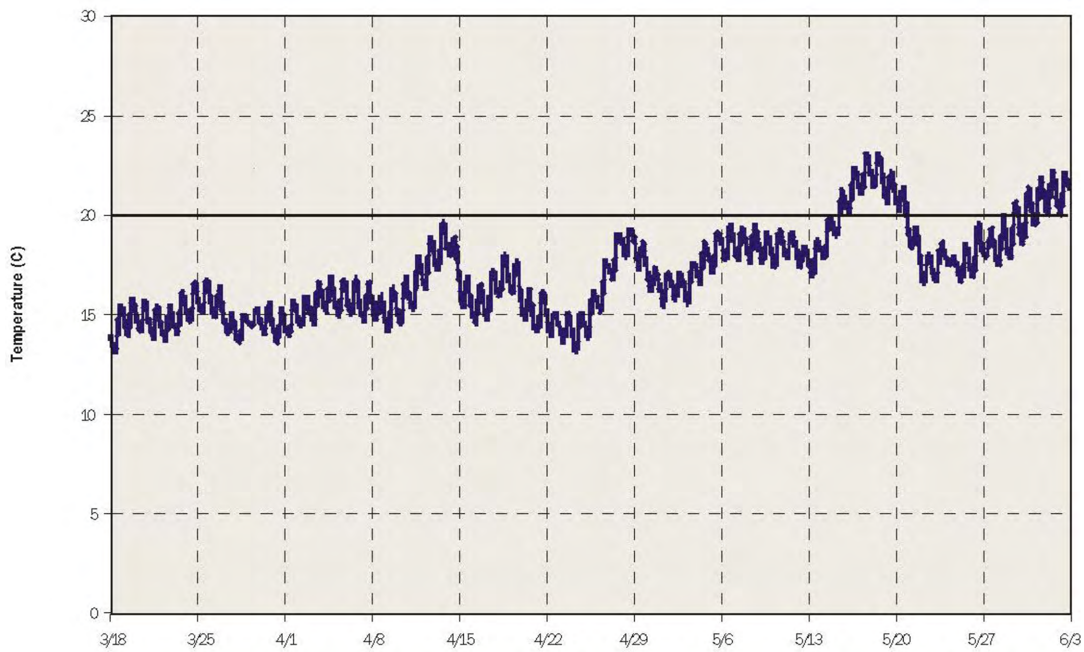


Figure 2-6. Water temperatures at the confluence (top) during April–May 2008

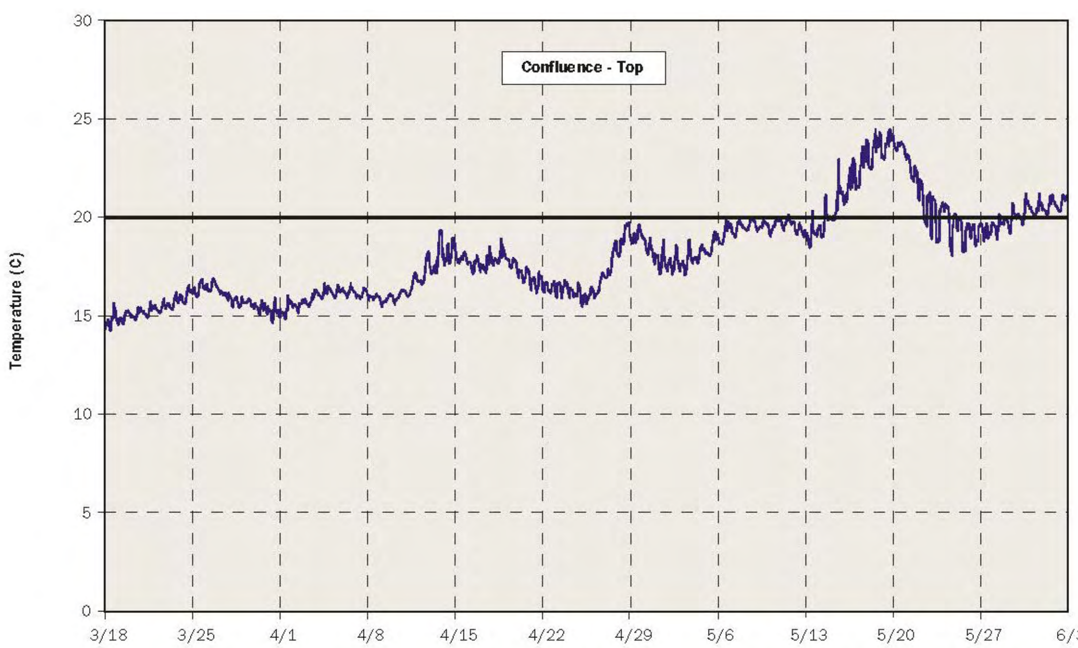


Figure 2-7. Water temperatures at Chipps Island during April–May 2008

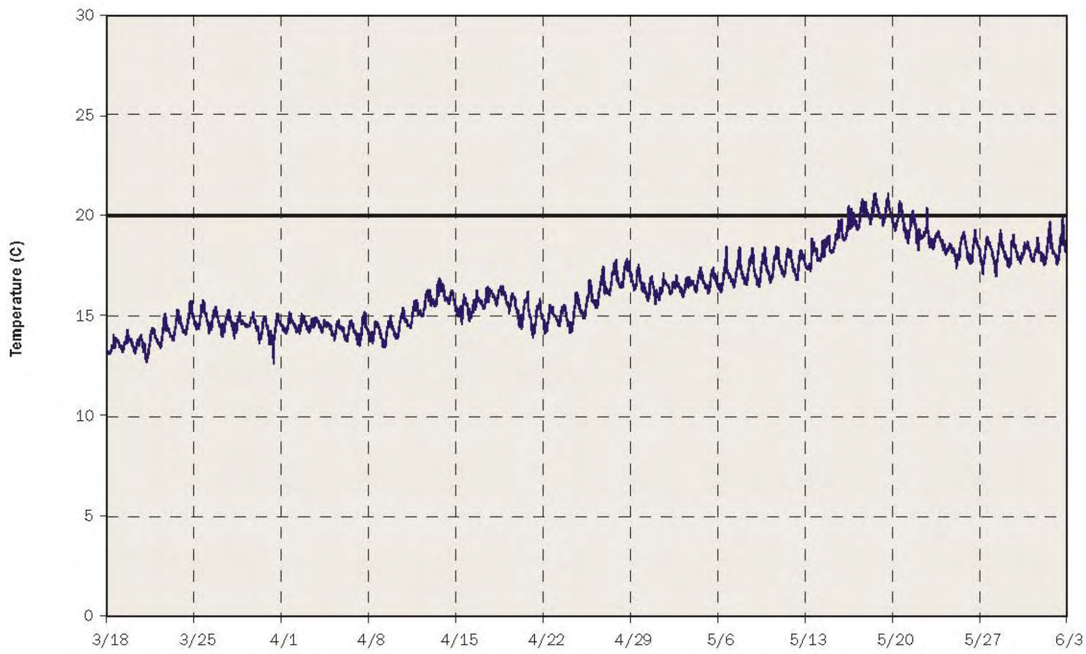
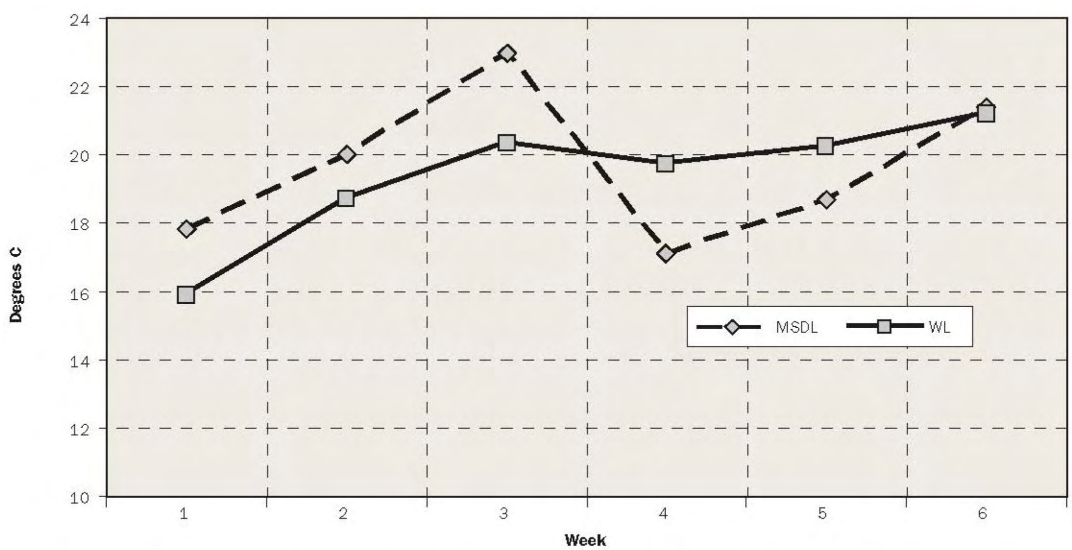


Figure 2-8. Mean weekly water temperature in wet lab (WL) tank and in the San Joaquin River at Mossdale (MSDL)



Methods

On May 2, 2008, 40 “dummy-tagged” Chinook juveniles (implanted with non-functioning sonic tags) were transported from MRH to the CNFHC wet lab. The fish had been tagged in 2 separate lots and were held in separate sections of a 750-L rectangular tank supplied with 19 L/minute of single-pass, ozone- treated water at temperatures similar to those of the San Joaquin River (Figure 2-9).

Water temperature was monitored hourly with an Onset StowAway temperature logger. Daily mean water temperatures at Mossdale (http://cdec.water.ca.gov) were examined to approximate the San Joaquin

River temperatures experienced by the MRH-released salmon. A commercial salmon diet (Silver Cup Salmon #2) was fed at 1.2% of body weight per day. Kidney tissue was collected from mortalities for imprints, histology, and bacterial culture.

Figure 2-9. Fish holding tanks used for health studies of tagged fish

Saltwater Challenge. Four to 7 salmon were held in a 0.03-m^3 cage within a 628-L tank supplied with 10-27 mg/L saltwater (Instant Ocean aquarium salt mix). The water was recirculated through a chiller (12 °C to 13 °C) and aerated. The salinity was raised from 10 to 20 mg/L at 32 hours and from 20 to 27 mg/L at 64 hours of the challenge. At 96 hours, all fish were rapidly netted and euthanized with an overdose of MS-222 in saltwater. Then they were gently dried, weighed to the nearest 0.1 g, measured for fork length (mm), and bled into a heparinized microhematocrit tube from the severed caudal peducle, and their gill lamellae were placed into SEI buffer and frozen at -70 °C. An imprint was made with kidney tissue for *Renibacterium salmoninarum* direct fluorescent antibody testing, and the remaining kidney was fixed in Davidson's fixative for 24 hours, transferred to 50% ethanol, and later processed for 6 microgram (μm) paraffin sections stained with hematoxylin and eosin. After centrifugation, hematocrit was recorded for each blood sample. Plasma was frozen for later sodium measurement (flame photometer) as well as magnesium and total protein measurements (colorimetric assays). Gill Sodium-Potassium - Adenosine Triphosphatase activity (ATPase = μmoles ADP / mg protein / hr) was assayed by the method of McCormick and Bern (1989). Condition factor was calculated as: $KFL = (Wt / FL^3) * 10{,}000$). Plasma chemistry data were analyzed by analysis of variance (ANOVA) (one-way on means or Kruskal-Wallis on ranks).

PKD Score. Each kidney section was scored 0, 1, 2, or 3 for Tb location in the kidney and occurrence of kidney inflammation. These scores were multiplied by 3 to obtain weight factors.

0 = no Tb observed, no inflammation
0x3 = 0 Tb score

1 = Tb only observed in blood sinuses, with no inflammation (early stage infection)
1x3 = 3 Tb score

2 = Tb observed in the kidney interstitium, with minor to moderate level of inflammation
2x3 = 6 Tb score

3 = similar to No. 2 but severe inflammation or granulomas, or both, observed (disease state)
3x3 = 9 Tb score

A fish was considered anemic if its hematocrit was less than or equal to 25% and it was given an anemia score of 6. The PKD score was a summation of the Tb (0, 3, 6, and 9) and anemia (0, 6) score. PKD scores ranged from 0 (normal) to 15 (clinical disease).

Results and Discussion

Mean weekly water temperature was increased from 16 °C to 21 °C over the 6-week study and was relatively similar to the temperature profile at Mossdale (Figure 2-8). The salmon showed a poor feed response throughout the study. Eight mortalities (out of 40 fish; 20% of fish) occurred to salmon held in fresh water between May 14 (9 days post-transferred [dpt]) and June 12 (40 dpt).

All exhibited clinical signs of PKD, such as pale gills (anemic) as well as swollen spleen and kidney. Aeromonid bacteria (motile gram-negative and cytochrome oxidase-positive) were isolated from 2 of 3 mortalities assayed. It is assumed that these opportunistic bacteria were not the primary cause of death, but were secondary infections. Histological examination of mortalities did not demonstrate significantly different kidney pathology than live cohorts sampled at similar times. There was no difference in mortality between the 2 tag lots, and the population was combined on May 23 (21 dpt). One mortality had shed its tag, and another showed hemorrhage associated with the tag suture. One to 3 cells resembling *Renibacterium salmoninarum* were observed in 2 of 39 kidney DFAT imprints. This low-level infection has been seen in previous MRH release groups and does not appear to be a health threat for the smolts (Nichols and Foott 2002). It appears that PKD was the predominant cause of death.

Histological Results. It appears that the population was experiencing clinical PKD at the time of the first saltwater challenge on May 23 (21 dpt). Parasites were observed in the kidney interstitium and often were associated with varying degrees of inflammation (Figure 2-10). There was a 62-percent incidence of clinical PKD (score greater than 9) observed in all 39 salmon sampled for kidney histology. The prevalence of clinical PKD ranged from 50% in the May 23 sample to 69% in the June 6 sample. It can be argued that the June 6 challenge population was affected by PKD to the greatest degree, because 6 of the 13 fish in this saltwater challenge were judged to be anemic. These data are reflected in the higher mean PKD score (Table 2-4).

Figure 2-10. High-magnification micrograph (600x) of kidney showing *Tetracapsuloides byrosalmonae*

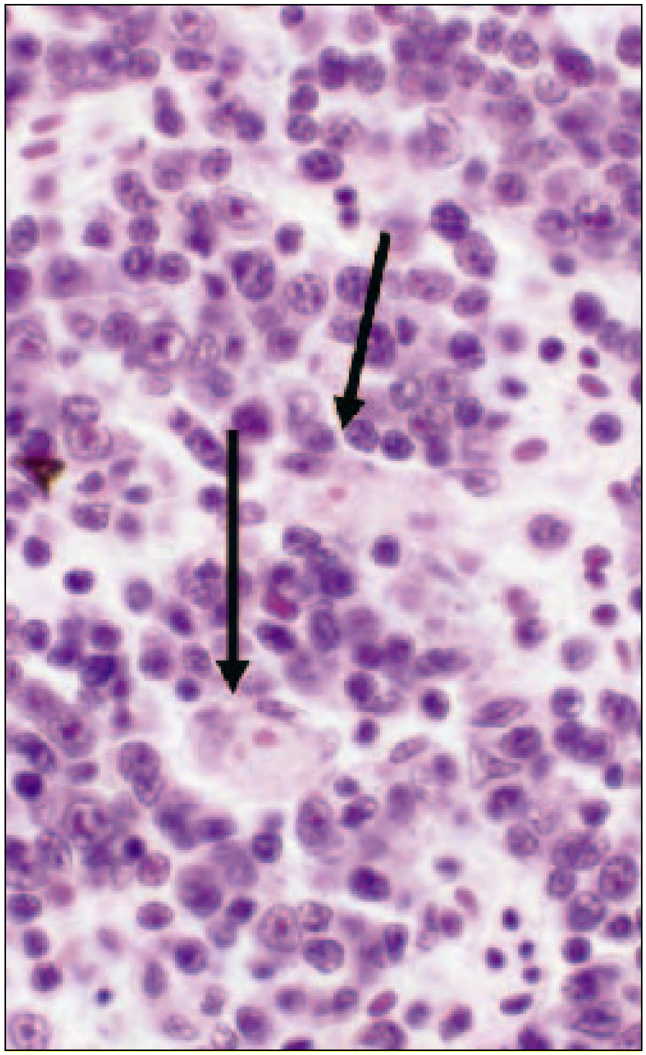


Table 2-4. Saltwater challenge data for Merced River Hatchery Chinook groups[a]

Date	May 23	June 6	June 15
Weight (g)	16.68 (2.8)	18.88 (3.8)	17.34 (4.1)
Fork length (mm)	115 (6)	118 (6)	118 (7)
Condition factor (KFL)	1.10 (0.11)	1.14 (0.12)	1.03 (0.10)
Plasma			
Number sampled	12	12	7
Sodium (mmol/L)	147.5 (4.7) a	151.6 (std = 8.7) ab	162 (std = 11.9) b
Protein (g/dL)	1.54 (0.35)	1.70 (std = 0.19)	1.68 (std = 0.21)
Magnesium (g/dL)	2.35 (0.56)	2.25 (std = 0.05)	3.06 (std = 1.29)
Hematocrit	32% (1)	27% (6)	27% (8)
ATPase** (mmol ADP)	3.79 (1.12) a	2.27 (0.78) b	3.02 (1.04) ab
PKD score	8	10	9

[a] Mean (std) for weight (g), fork length (mm), condition factor (KFL), plasma sodium (millimoles/liter [mmol/L]), plasma protein and magnesium (grams/deciliter [g/dL]), gill ATPase activity (mmol ADP/mg protein/h), and mean PKD score. Plasma data from 1 fish in the June 6 challenge was excluded due to extreme values indicating probable contamination. Subscripts (a, ab, b) indicate statistically significant relationships among groups ($P < 0.05$, ANOVA).

Saltwater Challenge. MRH salmon had high survival and maintained normal plasma constituent levels after 96 hours of increasing salinity. Hedrick and Aronstien (1987) reported similar findings with Tb-infected juvenile Chinook held in salt water. The only mortality occurred in the June 13 challenge. No statistically significant difference ($P < 0.05$) was observed in condition factor (KFL), plasma protein or plasma magnesium values (Table 2-4). The June 13 (42 dpt) challenge group had significantly higher plasma sodium levels than the May 23 (21 dpt) group; however, all sampled fish had concentrations below 170 mmol/L. Blackburn and Clarke (1987) report that 170 mmol/L is a threshold value for successful ion regulation in juvenile Chinook in 24-hour saltwater challenges.

Although it is not statistically significant, fish in the June 13 challenge had 4 indicators (reduced KFL, elevated magnesium and sodium, and lower gill ATPase activity) of osmoregulatory impairment. It is unclear how PKD is related to these changes, because the kidney histopathology was not judged to be different from the June 6 sample group. It is possible that chronic stress due to disease and high-water-temperature rearing were affecting osmoregulation. Reduced condition factor can occur when the fish is dehydrated, and altered divalent ion (Mg^{2+}) regulation would indicate kidney dysfunction (Clarke and Hirano 1995).

Sodium regulation occurs primarily in the gill and should not be affected directly by kidney inflammation. A freezer failure resulted in the movement of gill ATPase samples from -80 °C to -20 °C for several days. The effect on activity is unknown but could have caused a general reduction in the entire sample set. The range of ATPase activity values (1 to 6 mmol ADP/mg protein/hour) were much lower than gill samples from previous VAMP studies (Table 2-4). The 2008 data are viewed as comparative between challenge groups but are suspect for accurate activity levels. The May 23 group had significantly higher activities than the June 6 group ($F= 7.217$, $P= 0.003$).

Significance to VAMP Study. It is unlikely that PKD affected the short-term performance of the 2 VAMP release groups (April 29–May 1 and May 6–May 8), because the first saltwater challenge occurred 2 weeks after the first tagged cohort had been released into San Joaquin River. The May 23 group appeared to be just entering a clinical phase of disease (44% with a moderate PKD- 6 score and only 17% anemic). Only 1 freshwater mortality occurred prior to May 26.

The 2008 MRH salmon responded in a similar manner as in 2005 (Foott et al. 2007). Anorexia and anemia were prevalent in the PKD-affected salmon. Cumulative mortality due to PKD was 27% in 2005, compared with 20% in 2008. Survival in seawater was high in both years. It is unclear how to separate the effects of PKD from extended rearing in high water temperatures on saltwater adaptation. As in 2005, histopathology rating of the kidney (PKD score) was not informative for predicting saltwater adaptation. In order to examine the effect of PKD on early estuary and ocean survival, it is advisable to employ longer-term saltwater rearing (e.g., Bodega Marine Laboratory).

The Survival Model

The statistical model is based on the classic release-recapture models of Cormack (1964), Jolly (1965), and Seber (1965) and the route-specific survival model of Skalski et al. (2002). A key feature of the hydrophone network is the inclusion of independent double-detection arrays at several sites. The model uses these double-detection arrays to estimate a detection probability at each double-array site, thereby allowing estimation of distribution at junctions and the separation of detection and survival probabilities for the last reach (i.e., the sites identified in Figure 2-3 as JPT/TMS to MAL). When the assumptions of the survival model are met, this approach provides robust estimates of survival and route distribution probabilities (Table 2-5) that have not been attainable in prior studies. Specifically, robust estimates of survival through the system were anticipated for: migrants that enter the central Delta through Old River (S_{CDA}), migrants that enter the central Delta through Turner Cut (S_{CDB}), and migrants that remain in the main stem of the San Joaquin River until passing Turner Cut (S_3, S_4, S_5, and S_6). Additionally, the model will provide estimates of distribution probabilities at the junctions of Old River and Turner Cut (A and B, respectively). By comparing these survival probabilities and relating them to route distribution probabilities, one can elucidate the effects of migration pathway (i.e., entering the central Delta though either of these pathways) on overall survival through the Delta.

Estimating Overall Survival and Other Derived Parameters

In addition to the reach- and route-specific parameters identified (Table 2-5), any number of parameters may be derived as a function of these individual parameters. For example, one may wish to estimate "overall" survival ($S_{overall}$, the probability of survival from release at Durham Ferry to Mallard Island for all tagged fish) for comparison to previous and future studies. From the full model, the point estimate can be calculated as the weighted product of all reach- and route-specific survival probabilities:

$$S_{overall} = S_1{*}S_2{*}S_3{*}(1\text{-}A){*}S_4{*}S5{*}S6{*}(1\text{-}B){*}S_7 + S_1{*}S_2{*}S_{CDA}{*}A{*}S_7 + S_1{*}S_2{*}S_3{*}(1\text{-}A){*}S_4{*}S_5{*}S_{CDB}{*}B{*}S_7$$

$$= \left(\begin{array}{l}\text{Overall survival for}\\ \text{fish that } \textbf{remain in}\\ \textbf{the main stem}\end{array}\right) + \left(\begin{array}{l}\text{Overall survival for fish}\\ \text{that } \textbf{enter Central}\\ \textbf{Delta through OLD}\end{array}\right) + \left(\begin{array}{l}\text{Overall survival for fish}\\ \text{that } \textbf{enter Central Delta}\\ \textbf{through TRN}\end{array}\right)$$

Table 2-5. Definitions of survival and route entrainment parameters

Parameter	Definition
S_1	Survival from Durham Ferry to SJO(s)
S_2	Survival from SJO(s) to SJO(n)/OLD
S_3	Survival from SJO(n) to STP(s) or survival from release to STP(s) for fish released at Stockton
S_4	Survival from STP(s) to STP(n)
S_5	Survival from STP(n) to SJT/TRN
S_6	Survival from SJT to TMS/JPT/SWP/CVP (including fish that enter the central Delta through MR, OSJ, and FAL)
S_7	Survival from TMS/JPT/SWP/CVP to MAL
S_{CDA}	Survival from OLD to TMS/JPT/SWP/CVP for fish that enter the central Delta through OLD
S_{CDB}	Survival from TRN to TMS/JPT/SWP/CVP for fish that enter the central Delta through TRN
A	Of fish that enter the central Delta through Old River, proportion of those that survive to OLD/SJO(s)
B	Of fish that enter the central Delta through Turner Cut, proportion of those that survive to TRN/SJT
S_{36}	Survival from SJO(n) to TMS/JPT/SWP/CVP for fish that remain in the main stem through this reach (this parameter is derived for direct comparison to S_{CDA})
$S_{overall}$	Survival from Durham Ferry to MAL or from Stockton to MAL for fish released at Stockton
S_{CC}	Survival from CCFB to SWP

Further, an estimate of the precision (i.e., standard error) about $S_{overall}$ can be made by using the "Delta" method (Seber 1982). Alternatively, an estimate of the overall survival can be made directly in a simplified model, where *N* fish are released at Durham Ferry, and *n* fish are detected at Mallard Island with a detection probability of *p*. Both methods should result in the same parameter estimates and associated estimates of precision; however, the latter requires constructing a new model and input data set. Thus, the method of deriving parameters from individual parameter estimates in a single model is often preferred. Another key derived parameter is S_{36}: the probability of surviving from SJO(n) to TMS/JPT for fish that remain in the main stem through this reach. A comparison of S_{36} to S_{CDA} will determine whether survival to JPT/MAL is lower for fish that enter the central Delta through Old River than for those that remain in the main stem.

Model Selection: Pooling Data between the Two Release Sites

A large proportion of tagged fish released at Durham Ferry are expected to enter the central Delta though Old River, effectively reducing sample sizes in the lower main stem San Joaquin River. For this reason, releases at Stockton are intended to supplement sample sizes in the lower main stem San Joaquin River. Under the full model (Figure 2-11), all parameters are estimated separately for each release site. Ideally, however, survival and entrainment probabilities could be pooled among the 2 releases to effectively increase the sample size and provide increased precision about each parameter estimate. A set of candidate models will be developed to represent pooling various combinations of parameters, where no parameters are pooled in the full model (i.e., least reduced) and all possible parameters are pooled in the most reduced model. Model selection (Burnham and Anderson 1998) will be used to select the most parsimonious model (i.e., determine which parameters may be pooled). Thus, pooled estimates will only be reported when supported by model selection.

Predator Studies

If acoustic-tagged salmon were consumed by an untagged predatory fish, and the predator were to swim past a fixed-station acoustic receiver prior to tag defecation, data collected by the receivers would likely be misinterpreted as live salmon passing fixed stations. This circumstance would bias the juvenile salmon survival estimates high. Thus, data were needed on predator movements to assist in the interpretation of study results. Thirty striped bass were tagged with acoustic transmitters (tags; model 795-G, HTI) to monitor fish movements and behavior during the VAMP study. The 3.1-g tags measuring 11 mm by 25 mm were surgically implanted in striped bass caught in the vicinity of the Tracy Fish Collection Facility. Tagged bass were released immediately upstream of the trashracks at the facilities. The acoustic transmitters (model 795-G) were similar to but larger than the 0.7-g transmitters (model 795-S) implanted in salmon smolts. The transmitter batteries were expected to last for the duration of the 1-month study. Each transmitter was individually identifiable and did not overlap with smolt transmitters. Movements of tagged bass were monitored with the fixed-station acoustic receiver (data logger) network deployed to monitor smolts during the VAMP study (Figure 2-3). Each fixed-station receiver recorded the unique tag code and date/time of passing acoustic-tagged bass. These data were anticipated to provide information on striped bass movements within the study area and possible affinity to specific locales during spring 2008.

Figure 2-11. Schematic of proposed survival model for 2008 VAMP study for smolts released at Durham Ferry (a) and Stockton (b)

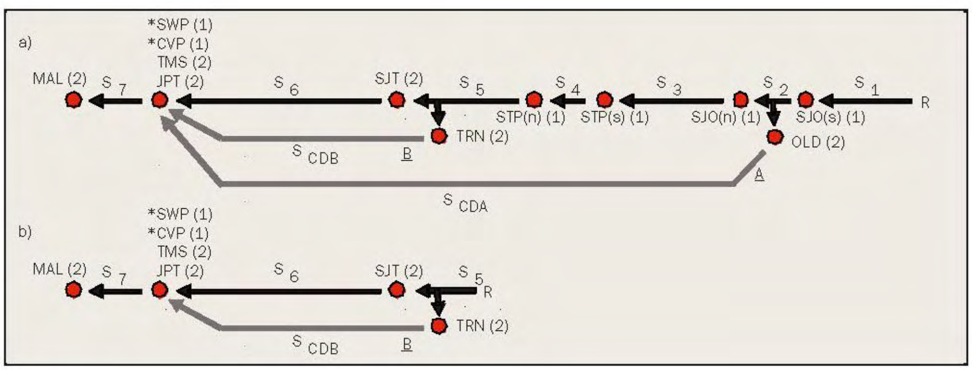


Figure 2-12. **Comparison of Antioch and Chipps Island survival estimates and differential recovery rates (DRRs) or combined differential recovery rates (CDRRs) compared with differential ocean recovery rates for 1996–2005 CWT releases**

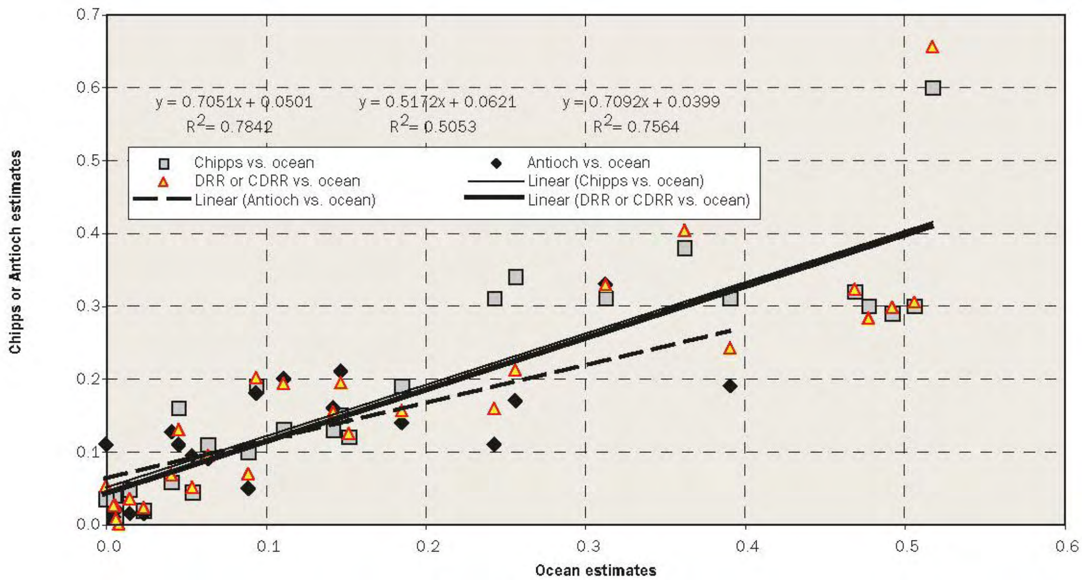


Table 2-6. Absolute survival estimates and differential recovery rates based on Chipps Island, Antioch, or ocean recoveries of MRH salmon released as part of south Delta studies between 1996 and 2006

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases: Release number	CWT smolt releases: Release site	CWT smolt releases: Release date	Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates: Chipps Island	Absolute survival estimates: Antioch	Differential recovery rates: DRR or CDRR	Differential recovery rates: Ocean DRR
1996	061110412	22,198	Dos Reis	May 1	2		3				
	061110413	25,414	Dos Reis	May 1	2		37				
	061110414	16,050	Dos Reis	May 1	1		8				
	061110415	31,208	Dos Reis	May 1	5		10				
	061110501	46,190	Jersey Point	May 3	39		186				
	Effective release	94,870	Dos Reis		10		58	0.120		0.125	0.152
	Effective release	46,190	Jersey Point		39		186				
1997	062545	48,973	Dos Reis	Apr 29	9		180				
	062546	53,483	Dos Reis	Apr 29	7		168				
	062547	51,576	Jersey Point	May 2	27		356				
	Effective release	102,456	Dos Reis		16		348	0.290		0.298	0.492
	Effective release	51,576	Jersey Point		27		356				
	062548	46,674	Dos Reis	May 8	5		90	0.300		0.283	0.477
	062549	47,534	Jersey Point	May 12	18		192				
1998	61110809	26,465	Mossdale	Apr 16	25		60				
	61110810	25,264	Mossdale	Apr 16	31		39				
	61110811	25,926	Mossdale	Apr 16	32		58				
	61110806	26,215	Dos Reis	Apr 17	34		48				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
1998 (cont.)	61110807	26,366	Dos Reis	Apr 17	25		35				
	61110808	24,792	Dos Reis	Apr 17	34		62				
	61110812	24,598	Jersey Point	Apr 20	87		110				
	61110813	25,673	Jersey Point	Apr 20	100		91				
	Effective release	77,655	Mossdale		88		157	0.300		0.305	0.506
	Effective release	77,373	Dos Reis		93		145	0.320		0.323	0.469
	Effective release	50,271	Jersey Point		187		201				
1999	062642	24,765	Mossdale	Apr 19	8		128				
	062643	24,773	Mossdale	Apr 19	15		135				
	062644	25,279	Mossdale	Apr 19	13		132				
	062645	25,014	Dos Reis	Apr 19	20		151				
	062646	24,841	Dos Reis	Apr 19	19		225				
	0601110815	25,101	Jersey Point	Apr 21	34		334				
	062647	24,359	Jersey Point	Apr 21	25		387				
	Effective release	74,817	Mossdale		36		395	0.380		0.403	0.362
	Effective release	49,855	Dos Reis		39		376	0.600		0.656	0.517
	Effective release	49,460	Jersey Point		59		721				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2000	06-45-63	24,457	Durham Ferry	Apr 17	11	11	296				
	06-04-01	23,529	Durham Ferry	Apr 17	7	6	215				
	06-04-02	24,177	Durham Ferry	Apr 17	10	10	232				
	06-44-01	23,465	Mossdale	Apr 18	9	14	207				
	06-44-02	22,784	Mossdale	Apr 18	9	16	174				
	06-44-03	25,527	Jersey Point	Apr 20	24	50	649				
	06-44-04	25,824	Jersey Point	Apr 20	41	47	704				
	Effective release	72,163	Durham Ferry		28	27	743	0.310	0.190	0.242	0.391
	Effective release	46,249	Mossdale		18	30	381	0.310	0.330	0.329	0.313
	Effective release	51,351	Jersey Point		65	97	1353				
	601060914	23,698	Durham Ferry	Apr 28	7	8	46				
	601060915	26,805	Durham Ferry	Apr 28	5	15	45				
	0601110814	23,889	Durham Ferry	Apr 28	10	8	70				
	0601061001	25,572	Durham Ferry	May 1	48	76	358				
	0601061002	24,661	Jersey Point	May 1	30	76	230				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases: Release number	CWT smolt releases: Release site	CWT smolt releases: Release date	Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates: Chipps Island	Absolute survival estimates: Antioch	Differential recovery rates: DRR or CDRR	Differential recovery rates: Ocean DRR
2000 (cont.)	Effective release	74,392	Durham Ferry		22	31	161	0.190	0.140	0.156	0.185
	Effective release	50,233	Jersey Point		78	152	588				
2001	06-44-29	23,351	Durham Ferry	Apr 30	14	28	95				
	06-44-30	22,720	Durham Ferry	Apr 30	22	30	158				
	06-44-31	22,376	Durham Ferry	Apr 30	17	18	111				
	06-44-32	23,022	Mossdale	May 1	17	18	122				
	06-44-33	22,191	Mossdale	May 1	14	15	106				
	06-44-34	24,444	Jersey Point	May 4	50	156	470				
	06-44-35	24,993	Jersey Point	May 4	61	173	556				
	Effective release	68,447	Durham Ferry		53	76	364	0.340	0.170	0.212	0.256
	Effective release	45,213	Mossdale		31	33	228	0.310	0.110	0.159	0.243
	Effective release	49,437	Jersey Point		111	329	1026				
	06-44-36	24,029	Durham Ferry	May 7	2	8	17				
	06-44-37	23,907	Durham Ferry	May 7	5	11	45				
	06-44-38	24,054	Durham Ferry	May 7	2	10	28				
	06-44-39	23,882	Mossdale	May 8	4	8	25				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2001 (cont.)	06-44-40	25,310	Mossdale	May 8	4	11	27				
	06-44-41	25,910	Jersey Point	May 11	17	43	243				
	06-44-42	25,466	Jersey Point	May 11	27	53	335				
	Effective release	71,990	Durham Ferry		9	29	90	0.130	0.200	0.194	0.111
	Effective release	49,192	Mossdale		8	19	52	0.190	0.180	0.201	0.094
	Effective release	51,376	Jersey Point		44	96	578				
2002	06-44-71	23,920	Durham Ferry	Apr 18	4	11	33				
	06-44-72	25,176	Durham Ferry	Apr 18	9	20	96				
	06-44-73	23,872	Durham Ferry	Apr 18	4	12	74				
	06-44-74	24,747	Durham Ferry	Apr 18	4	20	67				
	06-44-57	25,515	Mossdale	Apr 19	6	13	76				
	06-44-58	25,272	Mossdale	Apr 19	7	29	69				
	06-44-59	24,802	Jersey Point	Apr 22	46	101	494				
	Effective release	50,787	Mossdale		13	42	145	0.150	0.210	0.194	0.147
	Effective release	48,930	Jersey Point		83	190	950				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2002 (cont.)	06-44-70	24,680	Durham Ferry	Apr 25	3	6	23				
	06-44-75	24,659	Durham Ferry	Apr 25	5	2	21				
	06-44-76	24,783	Durham Ferry	Apr 25	3	4	7				
	06-44-77	24,381	Durham Ferry	Apr 25	4	6	6				
	06-44-78	24,519	Mossdale	Apr 26	2	3	26				
	06-44-79	24,820	Mossdale	Apr 26	3	4	14				
	06-44-80	24,032	Jersey Point	Apr 30	18	43	307				
	06-44-81	22,880	Jersey Point	Apr 30	28	32	290				
	Effective release	98,503	Durham Ferry		15	18	57	0.160	0.110	0.130	0.045
	Effective release	49,339	Mossdale		5	7	40	0.110	0.090	0.094	0.064
	Effective release	46,912	Jersey Point		46	75	597				
2003	06-02-82	24,453	Durham Ferry	Apr 21	0	1	9				
	06-02-83	25,927	Durham Ferry	Apr 21	2	4	0				
	06-27-42	24,069	Durham Ferry	Apr 21	1	1	10				
	06-27-48	24,471	Mossdale	Apr 22	2	2	3				
	06-27-43	25,212	Mossdale	Apr 22	3	2	5				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2003 (cont.)	06-27-44	24,414	Jersey Point	Apr 25	57	71	265				
	Effective release	74,449	Durham Ferry		3	6	19	0.019	0.015	0.023	0.024
	Effective release	49,683	Mossdale		5	4	8	0.048	0.015	0.035	0.015
	Effective release	24,414	Jersey Point		57	71	265				
	06-27-45	24,685	Durham Ferry	Apr 28	0	0	6				
	06-27-46	25,189	Durham Ferry	Apr 28	0	0	0				
	06-27-47	24,628	Durham Ferry	Apr 28	0	0	4				
	06-27-49	24,180	Mossdale	Apr 29	0	0	5				
	06-27-50	24,346	Mossdale	Apr 29	1	0	0				
	06-27-51	25,692	Jersey Point	May 2	39	35	426				
	Effective release	74,502	Durham Ferry		0	0	10			0.000	0.008
	Effective release	48,526	Mossdale		1	0	5	0.010		0.007	0.006
	Effective release	25,692	Jersey Point		39	35	426				
2004	06-27-52	23,440	Durham Ferry	Apr 22	0	1	3				
	06-27-53	21,714	Durham Ferry	Apr 22	1	1	0				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2004 (cont.)	06-27-54	23,328	Durham Ferry	Apr 22	1	0	0				
	06-27-55	23,783	Durham Ferry	Apr 22	1	0	0				
	06-46-70	25,319	Mossdale	Apr 23	0	1	0				
	06-45-82	23,586	Mossdale	Apr 23	1	0	0				
	06-45-83	24,803	Mossdale	Apr 23	2	0	2				
	06-45-80	22,911	Jersey Point	Apr 26	25	22	129				
	Effective release	92,265	Durham Ferry		3	2	3	0.030	0.020	0.026	0.006
	Effective release	73,708	Mossdale		3	1	2	0.040	0.010	0.026	0.005
	Effective release	22,911	Jersey Point		25	22	129				
2005	06-46-72	23,414	Durham Ferry	May 2	5	0	5				
	06-46-73	23,193	Durham Ferry	May 2	2	2	3				
	06-46-74	23,660	Durham Ferry	May 2	4	3	3				
	06-46-75	23,567	Durham Ferry	May 2	1	1	0				
	06-46-97	22,302	Dos Reis	May 3	1	1	0				
	06-46-98	24,149	Dos Reis	May 3	1	3	0				
	06-45-91	22,675	Dos Reis	May 3	1	3	0				
	06-45-88	22,767	Jersey Point	May 6	32	31	30				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases			Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates		Differential recovery rates	
		Release number	Release site	Release date				Chipps Island	Antioch	DRR or CDRR	Ocean DRR
2005 (cont.)	Effective release	93,834	Durham Ferry		12	6	11	0.099	0.049	0.069	0.089
	Effective release	69,126	Dos Reis		3	7	0	0.035	0.110	0.052	0.000
	Effective release	22,767	Jersey Point		32	31	30				
	06-45-84	22,777	Durham Ferry	May 9	2	1	5				
	06-45-85	22,968	Durham Ferry	May 9	1	1	0				
	06-45-86	23,012	Durham Ferry	May 9	3	3	2				
	06-45-87	22,806	Durham Ferry	May 9	0	2	0				
	06-45-89	21,443	Dos Reis	May 10	3	5	4				
	06-45-90	23,755	Dos Reis	May 10	2	2	0				
	06-46-99	23,448	Dos Reis	May 10	1	0	0				
	06-47-00	23,231	Jersey Point	May 13	38	27	33				
	Effective release	91,563	Durham Ferry		6	7	7	0.044	0.094	0.051	0.054
	Effective release	68,646	Dos Reis		6	7	4	0.058	0.127	0.068	0.041
	Effective release	23,231	Jersey Point		38	27	33				
2006	06-47-13	24,703	Mossdale	May 4	7	5	0				
	06-47-14	24,315	Mossdale	May 4	2	4	0				
	06-47-16	25,602	Dos Reis	May 5	7	3	0				

Release year	San Joaquin River (Merced River origin) tag number	CWT smolt releases: Release number	Release site	Release date	Chipps Island recoveries	Antioch recoveries	Expanded adult ocean recoveries (age 1+–4+)	Absolute survival estimates: Chipps Island	Antioch	Differential recovery rates: DRR or CDRR	Ocean DRR
2006 (cont.)	06-47-15	26,192	Jersey Point	May 8	58	26	0				
	Effective release	49,018	Mossdale		9	9	0	0.080	0.180	0.115	
	Effective release	25,602	Dos Reis		7	3	0	0.120	0.110	0.122	
	Effective release	26,192	Jersey Point		58	26	0				
	06-47-21	25,105	Mossdale	May 19	2	0	0				
	06-47-22	24,008	Mossdale	May 19	0	0	0				
	06-47-24	23,980	Jersey Point	May 22	44	14	0				
	Effective release	49,113	Mossdale		2	0	0	0.030	0.000	0.017	
	Effective release	23,980	Jersey Point		44	14	0				

Survival through the Delta in Past Years

Ocean Recovery Information

Ocean recovery data of CWT salmon groups can provide an additional source of recoveries for estimating survival through the Delta. The ocean harvest data may be more reliable because of the greater number of CWT recoveries and the extended recovery period.

Adult ocean recovery data are gathered from commercial and sport ocean harvest checked at various ports by DFG. The Pacific States Marine Fisheries Commission database of ocean harvest CWT data was the source of recoveries through 2007. The ocean CWT recovery data accumulate over a 1- to 4-year period after the year a study release is made as nearly all of a given year-class of salmon have been either harvested or spawned by age 5. Consequently, these data are essentially complete for releases made through 2003 and are partially available for CWT releases made from 2004 to 2006 (no releases were made in 2007 and 2008). Differential recovery rates (DRRs) based on Chipps Island or ocean recoveries and combined differential recovery rates (CDRR) based on both Antioch and Chipps Island recoveries for salmon produced at MRH are shown in Table 2-6. Absolute survival estimates based on Chipps Island and Antioch survival indices are also included. The earlier releases were made as part of south Delta survival evaluations (1996–1999), and the later releases are associated with VAMP (2000–2006). Releases have been made at several locations: Dos Reis, Mossdale, Durham Ferry, and Jersey Point. The Chipps Island and Antioch survival estimates and CDRRs (Antioch and Chipps Island recoveries summed) or DRRs (Chipps Island recoveries only) are graphed in relation to the DRR using the ocean recovery information in Figure 2-12.

Results of this comparative analysis of survival estimates and DRRs for Chinook salmon produced at MRH show that there is general agreement between survival estimates and DRRs based on juvenile CWT salmon recoveries at Chipps Island and adult recoveries from the ocean fishery (r2=0.78); there is less agreement with Antioch trawling, which has fewer years of data; and additional comparisons need to be made as more data become available from recoveries of VAMP study fish in the ocean fishery.

San Joaquin River Salmon Protection

One of the VAMP objectives is to provide improved conditions to increase the survival of juvenile Chinook salmon smolts produced in the San Joaquin River tributaries during their downstream migration through the lower river and Delta. It is hypothesized that these actions to improve conditions for the juveniles will translate into greater adult abundance and escapement in future years than would otherwise occur without the actions.

To determine whether VAMP has been successful in targeting the migration period of naturally produced juvenile salmon, catches of unmarked salmon in the Kodiak trawl at Mossdale and in salvage at the CVP and SWP facilities were compared prior to and during the VAMP period.

Unmarked and Marked Salmon Captured at Mossdale

The default time period of VAMP (April 15 to May 15) was chosen based on historical data that indicated a high percentage of the salmon smolts emigrating from the San Joaquin tributaries passed into the Delta at Mossdale during that time. In 2008, the start of the VAMP period was shifted by 1 week, to April 22, to allow additional time for test fish to grow for use in the acoustic telemetry study. Densities (catch per 10,000 m^3) of unmarked juvenile salmon captured at Mossdale during January through June are shown in Figure 2-16. Unmarked salmon do not have an adipose clip or any other external mark (i.e., Panjet or Bismark brown) and can be juveniles from natural spawning or unmarked hatchery fish from MRH. On May 27, 2008, a total of 7,460 unmarked smolts were released at MRH, the only release of unmarked hatchery smolts from MRH during 2008. As in prior years, there is no way to determine how many unmarked hatchery smolts were captured in the trawl. No adipose-fin-clipped salmon were released from MRH during 2008.

A peak density of unmarked juvenile salmon at Mossdale occurred on May 16 and 19 (May 17–18 were not sampled), near the end of the VAMP period and immediately following an initial decrease in flows in the Tuolumne and Merced rivers (Figure 2-16). An earlier peak also occurred on April 28 (April 26–27 were not sampled) a few days after Vernalis flow exceeded 3,000 cubic feet per second (cfs). Densities may have been as high or higher on days when no sampling was conducted (i.e., sampling was only conducted 5 days/week). The size of the juvenile salmon captured in the Mossdale trawl during January through June is shown in Figure 2-15. Some salmon in the 50–69 mm range (parr) were in the catch from mid-April through May.

Figure 2-13. Salmon Smolts with surgically implanted coded wire tags

Figure 2-14. Surgically implanting coded wire tags in Salmon smolts

Salmon Salvage and Losses at Delta Export Pumps

Fish salvage operations at the CVP and SWP export facilities capture juvenile salmon and transport them by tanker truck to release sites in the western Delta. The untagged salmon are potentially from any source in the Central Valley. It is not certain which unmarked salmon recovered are of San Joaquin basin origin, though the timing of salvage and fish size can be compared with Mossdale trawl data and recovery data for tagged MRH smolts at the salvage facilities to provide some general indications about the origin of the unmarked fish. DWR estimated that the proportion of the water in the Clifton Court Forebay (CCF) of the SWP from the San Joaquin River increased from approximately 10% during early January to approximately 20% from late January through mid-March (based on Real Time Data and Forecasting Project water quality weekly reports from DWR's Office of Water Quality). The proportion gradually increased after mid-March and reached a high of approximately 65% in late May. The proportion gradually decreased during June to approximately 35%. It may be assumed that the proportion of the CVP water source from the San Joaquin River was similar in 2008.

The estimated salmon losses at the CVP and SWP are based on expanded salvage and an estimate of screen efficiency and survival through the facility and salvage process. The CVP pumps divert directly from the Old River channel, and direct losses are estimated to range from about 50% to 80% of the number salvaged. Four to 5 salmon are estimated to be lost per salvaged salmon at the SWP because of high predation rates in CCF. The SWP losses are therefore about 6 to 8 times higher, per salvaged salmon, than for the CVP. The loss estimates do not include any indirect mortality in the Delta due to water export operations or additional mortality associated with post-release predation.

Density of salmon encountering both of the export and fish salvage facilities off Old River is represented by the combined salvage and loss estimated per acre-foot (af) of water pumped. DFG and DWR maintain a database of daily, weekly, and monthly salvage data. The number and density of juvenile salmon that migrated through the system, the placement of the HORB, and the amount of water pumped by each facility are some of the factors that influence the number of juvenile salmon salvaged and lost. Density is an indicator of when concentrations of juvenile salmon may be more susceptible to the export facilities and salvage system. Additionally, salvage efficiency is lower for smaller-sized salmon (fry and parr), so their salvage numbers and estimated losses are underrepresented.

The size distribution of unmarked salmon in the Mossdale trawl (Figure 2-15) during January through June generally overlaps with the size distribution of those salvaged at the fish facilities (Figure 2-21; source: S. Greene, DWR). Based on comparisons with Mossdale data, it appears that some salmon salvaged before, during, and after the VAMP period could have been from the San Joaquin basin (Figure 2-16).

The weekly data covering the period of April 23 to May 20 approximated the 2008 VAMP period. A review of weekly data for January through June indicates that CVP and SWP salvage and losses started to increase in early April, peaked during late April through mid-May coincident to the VAMP period, and remained elevated through late May (Figure 2-17 and Figure 2-18). Salmon densities based on combined salvage and loss estimates were also highest during much of the VAMP period at the CVP and SWP (Figure 2-19); the peak at both facilities occurred during early May. As in other years, relatively large seasonal numbers and densities were observed before and after VAMP when exports approximated or exceeded flows at Vernalis (Figure 2-20).

Results of these analyses show that the 2008 VAMP test period coincided with the mid-portion of the San Joaquin River salmon smolt emigration period when migration densities were highest. Unfortunately, sampling at Mossdale was only conducted 5 days/week during the VAMP period rather than daily as in most recent years. Production estimates at Mossdale could be improved by ensuring that sampling is conducted daily when most salmon smolts are emigrating.

Figure 2-15. Mossdale Kodiak trawl individual daily fork lengths of juvenile Chinook salmon, January–June 2008

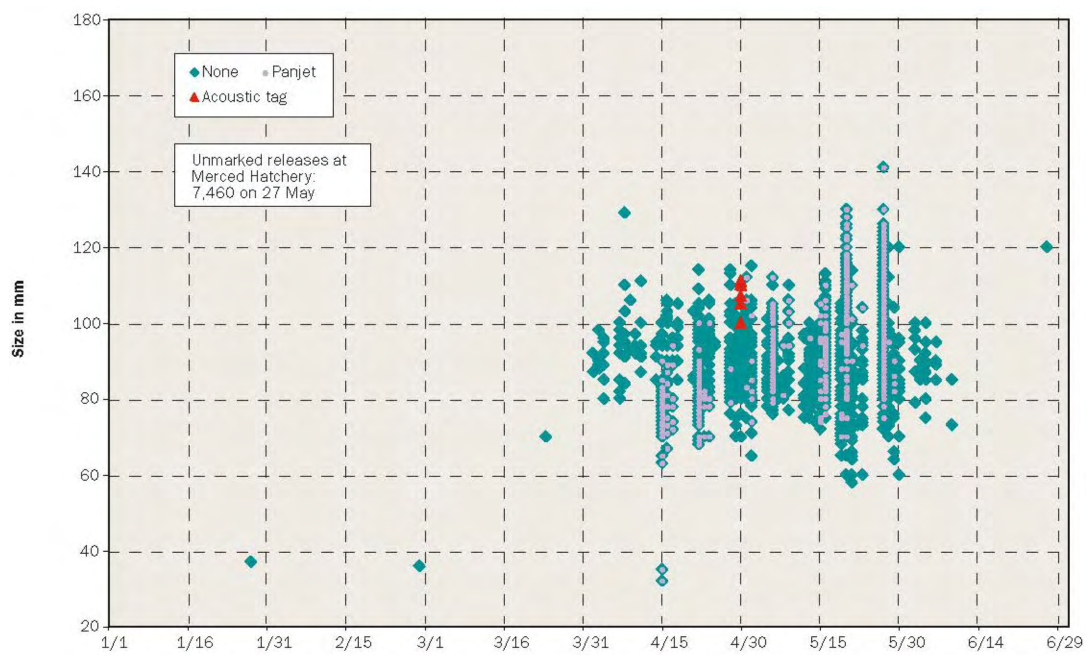


Figure 2-16. Average daily densities of unmarked salmon caught in the Mossdale Kodiak trawl

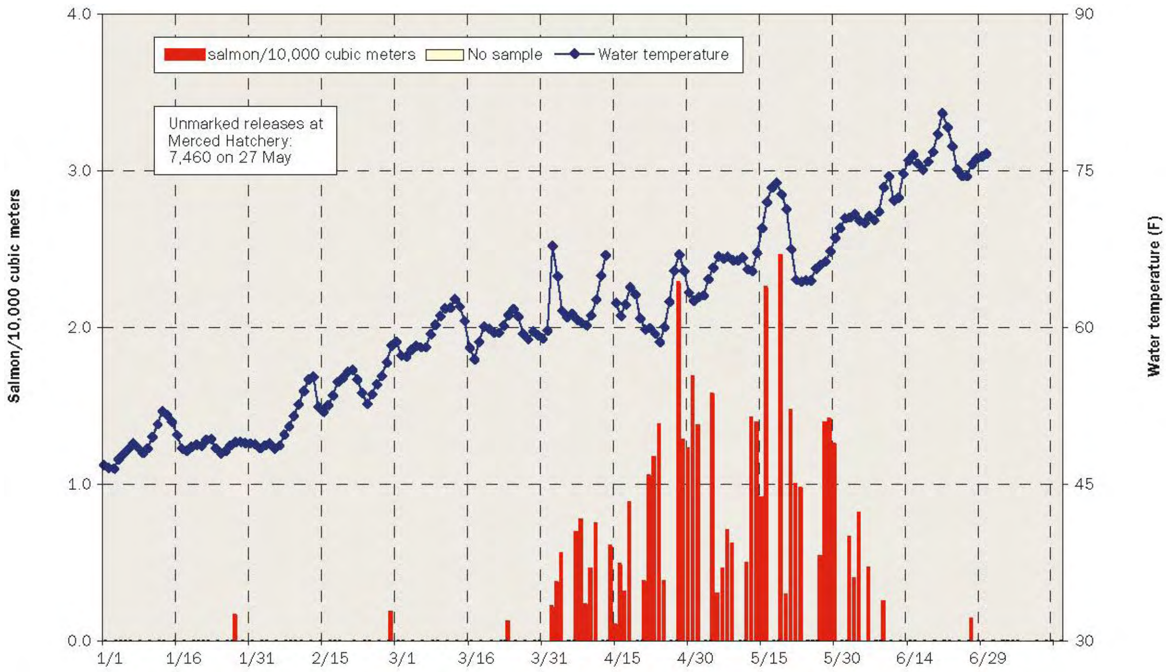


Figure 2-17. Central Valley Project estimated salmon salvage and loss, 2008

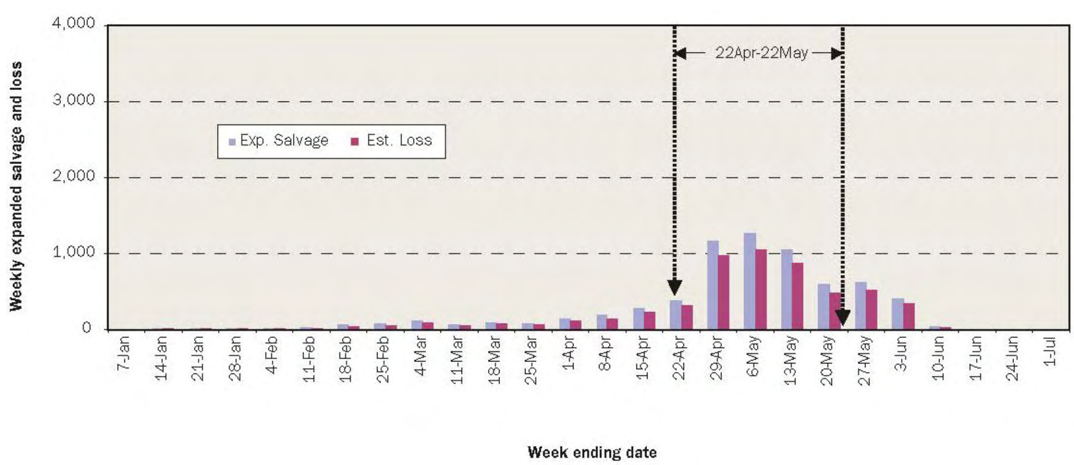


Figure 2-18. State Water Project estimated salmon salvage and loss, 2008

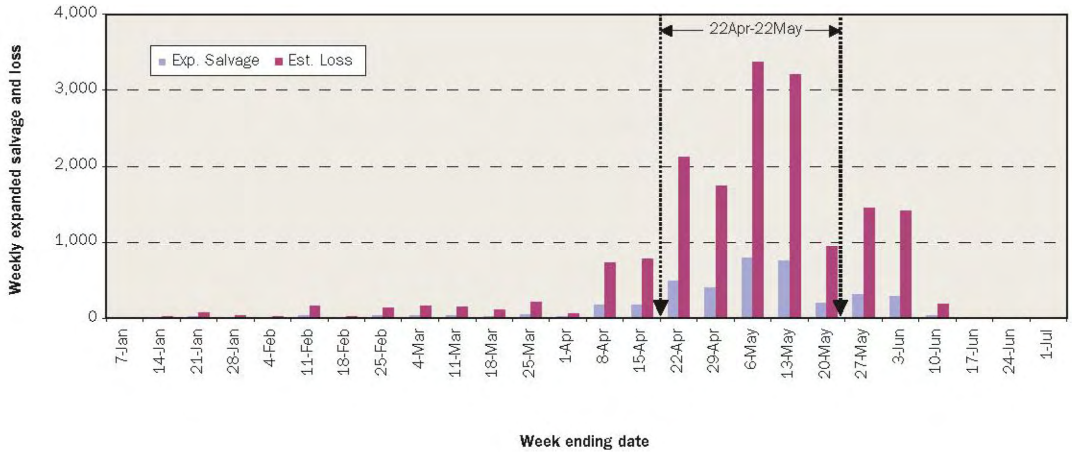


Figure 2-19. State Water Project and Central Valley Project combined salvage and loss density, 2008

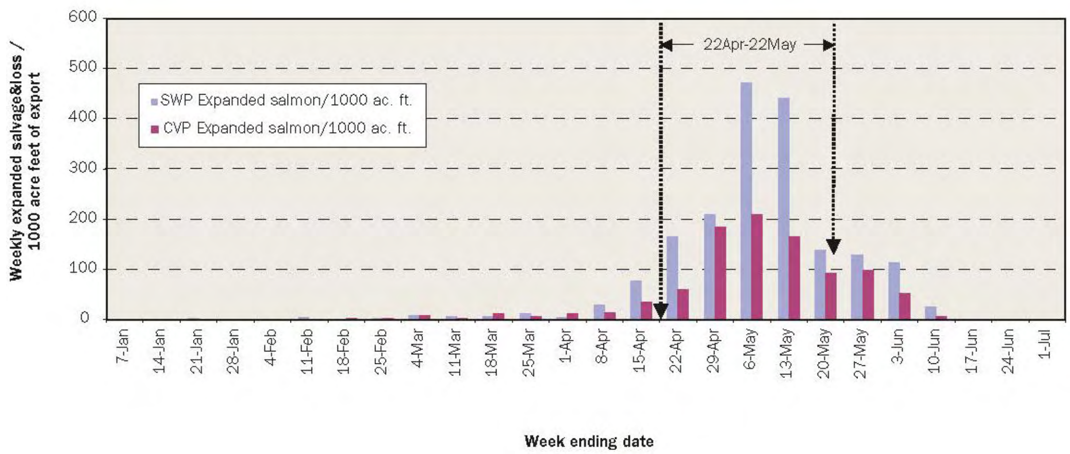


Figure 2-20. Weekly export rates and Vernalis flow, 2008

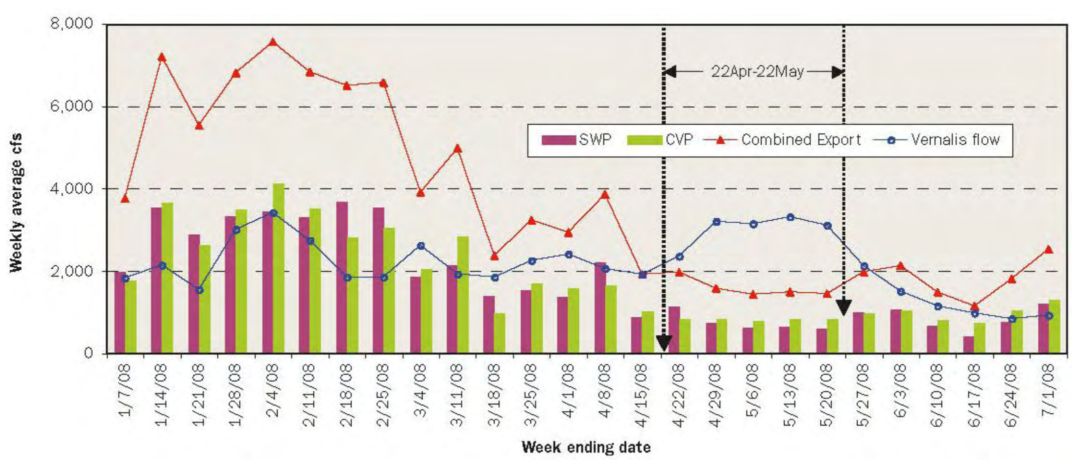
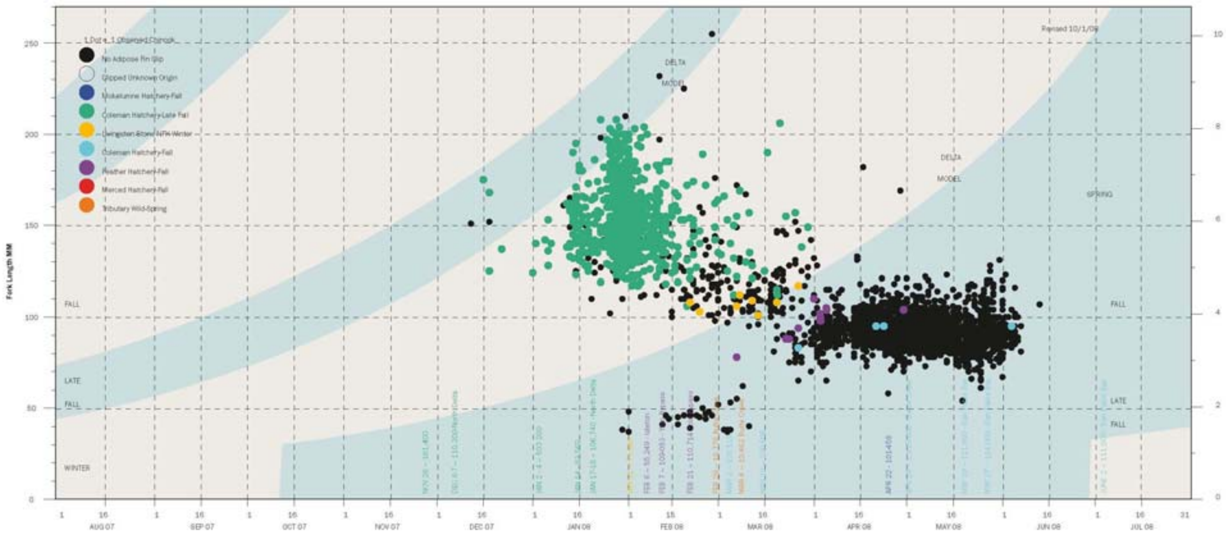


Figure 2-21. Observed Chinook salvage at the SWP and CVP Delta fish facilities August 1, 2007, through July 31, 2008 (11x17 large format. See separate PDF online)



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Chapter 3. Barrier Effects on State Water Project and Central Valley Project Entrainment

An annual summary of SWP and CVP salvage is included in this TBP report with the intention of evaluating whether seasonal temporary fish barriers reduce fishery impacts by reducing entrainment of fish at the Skinner fish facility (SWP) and Tracy fish facility (CVP).

Of particular interest in this chapter is the spring HORB, a barrier primarily intended to increase San Joaquin River Chinook salmon smolt survival by preventing them from entering Old River and eventually being entrained in the SWP and CVP fish facilities. However, the spring HORB was not installed in 1993, 1995, 1998, 2005, or 2006 because of high San Joaquin River flows. The spring HORB also was not installed in 2008 because of a court order (the Wanger decision, described in Chapter 1) intended to protect Delta smelt.

It is difficult to ascertain the effectiveness of the spring HORB by using salvage data, because of the complexities involved with analyzing a multitude of variables, including export rates, local population dynamics of fishes in the south Delta and Clifton Court Forebay, Delta hydrodynamics, and barrier influences of the south Delta flow. Another challenge of analyzing a variable such as salvage is the inability to accurately determine causal relationships between variables. As a result of these complexities, this chapter focuses solely on presenting the available data regarding changes in temporary barrier operations, project exports, and listed species salvaged at both the SWP and CVP facilities during 2008.

Data Collection

Skinner and Tracy salvage data were downloaded from the DFG Bay-Delta Office server at ftp://ftp.delta.dfg.ca.gov. Project water exports were provided by DWR staff from the Division of Operations and Maintenance, State Water Project Operations Control Branch, Operations Scheduling Section. Barrier operations were obtained from the TBP weekly updates and schedule of operations, which are posted on the DWR South Delta Branch website (http://baydeltaoffice.water.ca.gov/sdb/tbp/index_tbp.cfm). Installation information for 2008 for the spring HORB, MR barrier, Old River at Tracy (ORT) barrier, GLC barrier, and fall HORB are described in Table 3-1.

Table 3-1. Temporary barrier installations for 2008

Barriers	Beginning of site work	Beginning in-water work	Closure	Complete removal
Spring HORB	Not installed in 2008	Not installed in 2008	Not installed in 2008	Not installed in 2008
MR barrier	May 19, 2008	May 19, 2008	May 21, 2008	Nov 9, 2008
Old River near Tracy	May 12, 2008	May 12, 2008	Jun 4, 2008	Nov 25, 2008
GLC barrier	May 19, 2008	May 19, 2008	Jun 26, 2008	Nov 24, 2008
Fall HORB	Oct 1, 2008	Oct 2, 2008	Oct 16, 2008	Nov 9, 2008

Although all the temporary barriers are listed in Table 3-1, the spring HORB is the focus of this chapter because of its intended purpose as a fish barrier (the remaining barriers serve as agricultural barriers).

The 2008 BO released by NOAA Fisheries stated, “The Head of Old River Barrier is designed to improve migration conditions for Central Valley fall-run Chinook salmon originating in the San Joaquin River watershed during adult and juvenile migrations (i.e., fall and spring) by ‘blocking’ migratory movements into the Old River channel from the mainstem San Joaquin River." However, as shown in Table 3-1 above, the spring HORB was not installed in 2008.

Methods

Because reducing Chinook entrainment at the fish facilities was the initial priority of the spring HORB, graphs were prepared for each facility to show total water exported and Chinook salvage during the years 2005–2008 (Figures 3-1 and 3-2). This was done to gain a better understanding of Delta dynamics over the last 4 years in relation to salvage. In the study "Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversion in the Sacramento-San Joaquin Delta," by Kimmerer (2008), correlative analyses suggested that the proportion of fish salvaged increased with export flow. Because of this possible correlation between salvage counts and the amount of water exported, past TBP reports included graphs of daily water export data (expressed as percent relative exports) and fish salvage data plotted for listed species entrained at either the SWP or the CVP facility. Listed fish species include: Chinook salmon, steelhead, splittail, longfin smelt, and Delta smelt. Although the relationship between water exports and salvage at a pumping plant is still indeterminable, in order to present the data, these graphs for 2008 are also included here (Figures 3-3 through 3-12).

Fish Salvage Concerns

An examination of fish salvage as a sample of entrained fishes is complicated because of differences in how fish species and age groups respond to environmental conditions. The SWP and CVP fish facilities are not designed to effectively sample all fish equally. Salvage efficiency is related to the size of the fish, species, and age groups. In addition, because of the inherent variability in sizes of fish populations from year to year, significantly large proportions of stocks may be entrained because of their inability to escape the SWP and CVP pumps' zones of influence. Larval fishes are especially susceptible to entrainment.

Differences in SWP and CVP fish collection configurations complicate a comparison of the daily project salvage data relative to the position of species in the south Delta. The simple presence of Clifton Court Forebay prior to entry into the SWP fish facility may directly or indirectly alter salvage estimates at this facility.

Total water exports for the years 2005–2008 for SWP have decreased continuously (Figure 3-1), yet there has not been much variation in total water exported by the CVP (Figure 3-2). The decreasing trend in SWP exported water over time and the similar decreasing trend in Chinook salvage for this facility supports the theory that salvage is directly affected by exports. However, CVP Chinook salvage counts show the same decreasing trend despite exports being essentially the same over time. Data like these exemplify how unclear the relationship between water exports and salvage can be. In some years, these 2 variables may be more dependent on each other, and in other years, different variables, such as population declines, may provide a better estimate of salvage.

The data for Chinook salvage would be more likely to show any noticeable trends resulting from the use of temporary barriers over time than would salvage counts for other species, because of the spring HORB's proposed direct intention of decreasing the amount of Chinook entrained at the fish facilities. The noticeable decrease in Chinook salvage in 2007 could provide evidence of the benefits of the spring HORB because 2007 was the only year between 2005 and 2008 during which the spring HORB was put in place (Figures 3-1 and 3-2). However, it should be noted that pumping actually was stopped from June 1 to June 9, 2007, and the decline of Delta fish populations in general could be confounding factors in this qualitative analysis.

Figure 3-1. Total water exports and Chinook salvage for the State Water Project, 2005–2008

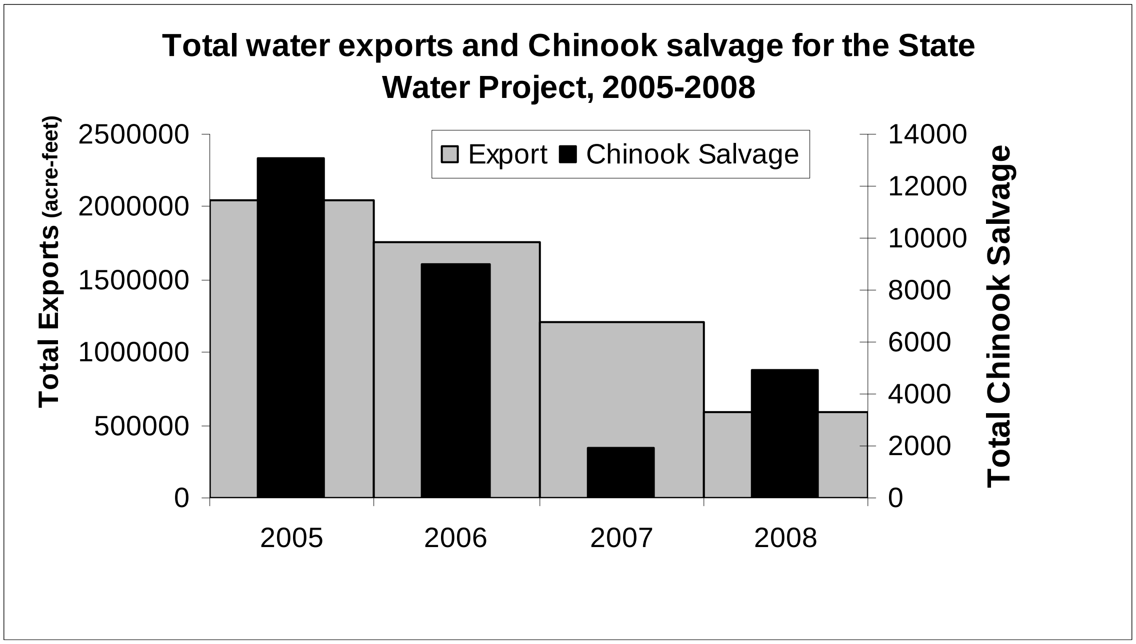
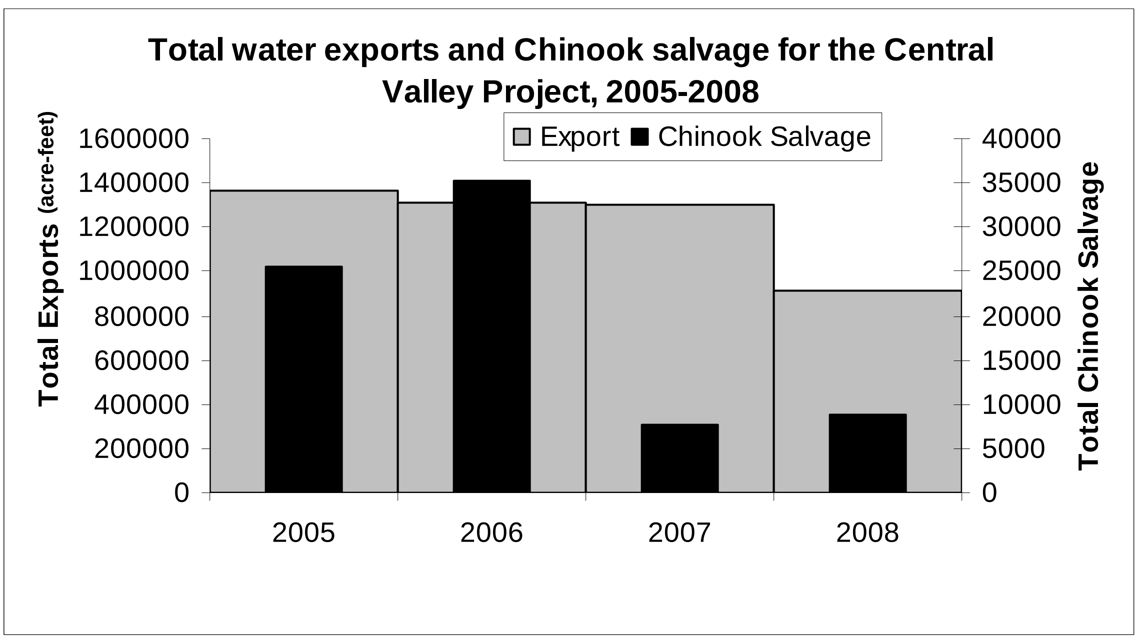


Figure 3-2. Total water exports and Chinook salvage for the Central Valley Project, 2005–2008



Salvage Data

Daily water export and fish salvage data were presented in graphical form (Figure 3-3 through Figure 3-12) using percent relative exports and listed fish species for the both the SWP and the CVP. These figures are described in Table 3-2 below.

Table 3-2. Salvage data figures in Chapter 3

Figure	Location	Dates	Species
3-3	SWP	Jan 1–Jun 15, 2008	Chinook salmon
3-4	CVP	Jan 1–Jun 15, 2008	Chinook salmon
3-5	SWP	Jan 1–Jul 15, 2008	Steelhead
3-6	CVP	Jan 1–Jul 15, 2008	Steelhead
3-7	SWP	Jan 1–Aug 15, 2008	Splittail
3-8	CVP	Jan 1–Aug 15, 2008	Splittail
3-9	SWP	Jan 15–Jun 15, 2008	Longfin smelt
3-10	CVP	Jan 15–Jun 15, 2008	Longfin smelt
3-11	SWP	Jan 5–Jul 10, 2008	Delta smelt
3-12	CVP	Jan 5–Jul 10, 2008	Delta smelt

As mentioned in the “Fish Salvage Concerns” section above, there are complications in drawing specific conclusions regarding the effect of the temporary barriers on fish populations using the available data. Water export fluctuation (both natural and human-induced) and the inherent variability in fish population dynamics from year to year, regardless of temporary barriers, make it difficult to accurately assess the data and make correlations. Therefore, export and salvage data are presented for documentation purposes only.

Recommendations

It appears that significant correlations between fish species’ densities and changes in water project hydrodynamics are complicated by variability of fish sampling and yearly water fluctuations. Because of this uncontrolled variability, the data collected for this report do not provide the ability to draw accurate conclusions. The use of these data for analysis would be aided by the inclusion of ecological data on fish populations in the Delta. For example, a comparison across years of the percent of the population salvaged would be much more indicative of any effects the spring HORB has on fish populations than direct salvage numbers. This type of data may be available from additional research activities, including DWR’s IEP studies and the operating criteria and plan (OCAP) for the CVP and the SWP studies. However, population estimates can be highly variable due to some of the same complexities that hinder our analyses of salvage data. It is recommended that future monitoring reports incorporate additional ongoing research data (i.e., IEP and OCAP data) to gain a more focused understanding of the baseline conditions of fish populations by year and compare those to salvage data and the use of the temporary barriers.

Figure 3-3. Percent relative exports and Chinook salvage for the State Water Project, January 1–June 15, 2008

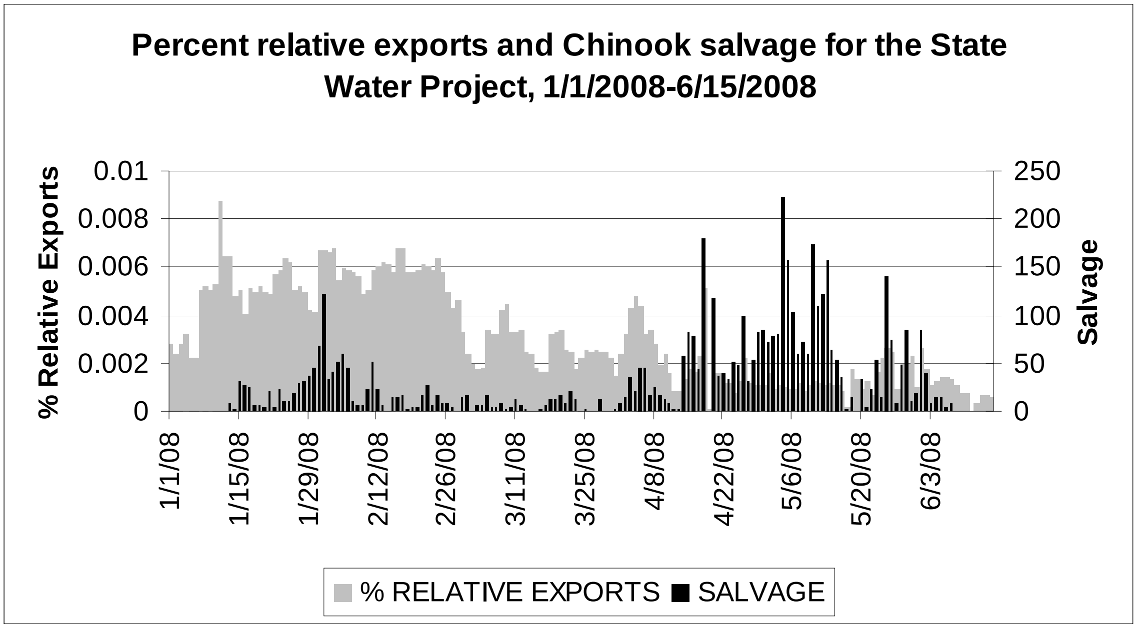


Figure 3-4. Percent relative exports and Chinook salvage for the Central Valley Project, January 1–June 15, 2008

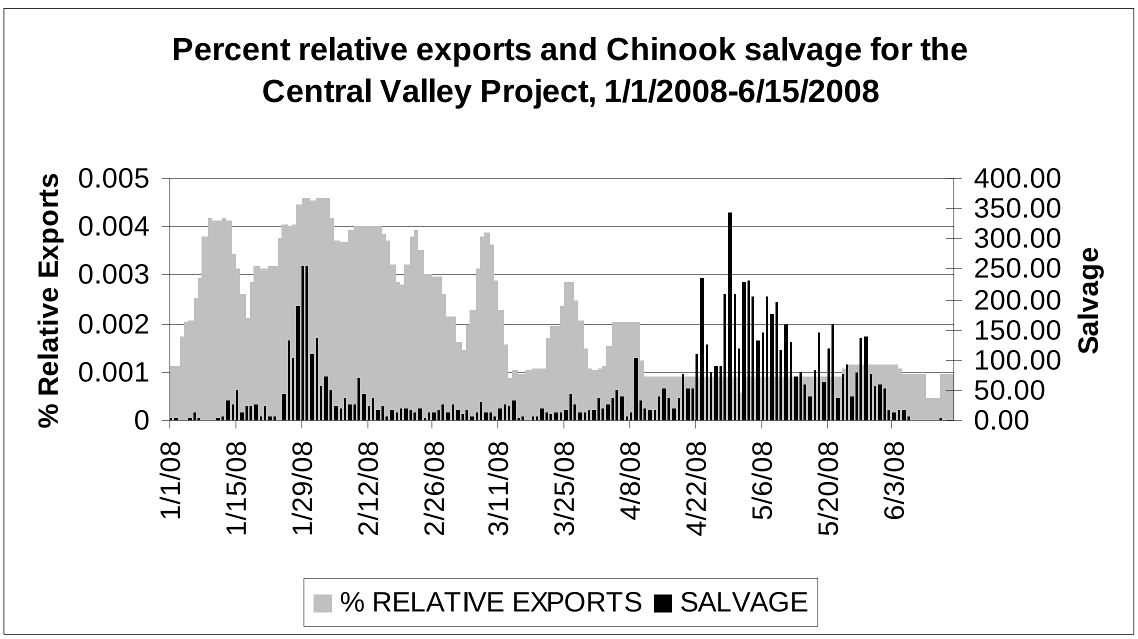


Figure 3-5. Percent relative exports and steelhead salvage for the State Water Project, January 1–July 15, 2008

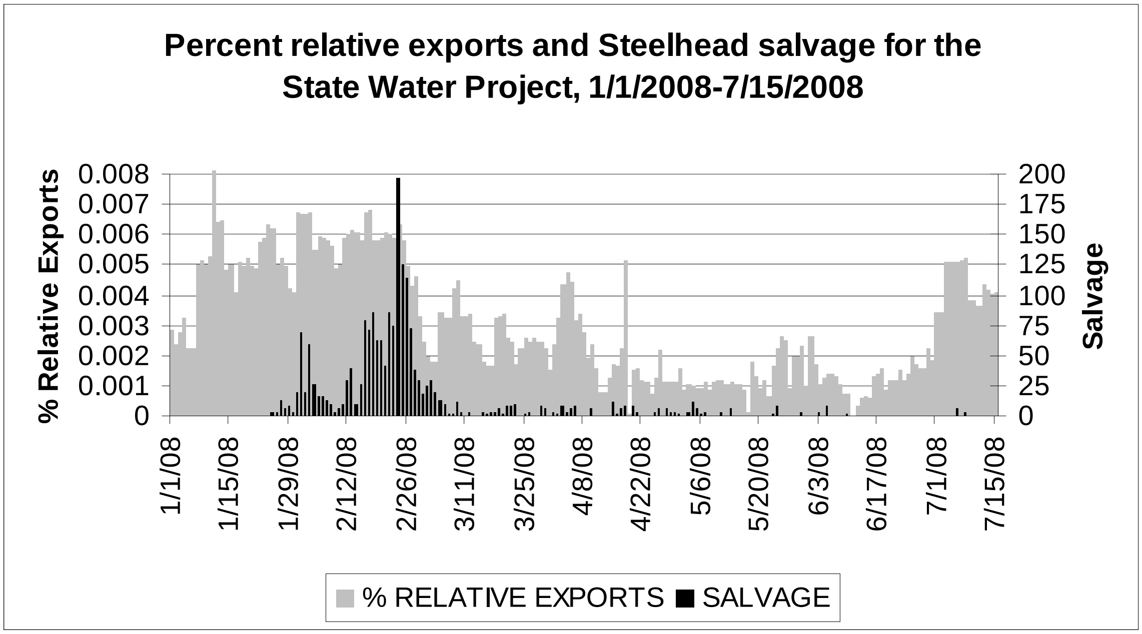


Figure 3-6. Percent relative exports and steelhead salvage for the Central Valley Project, January 1–July 15, 2008

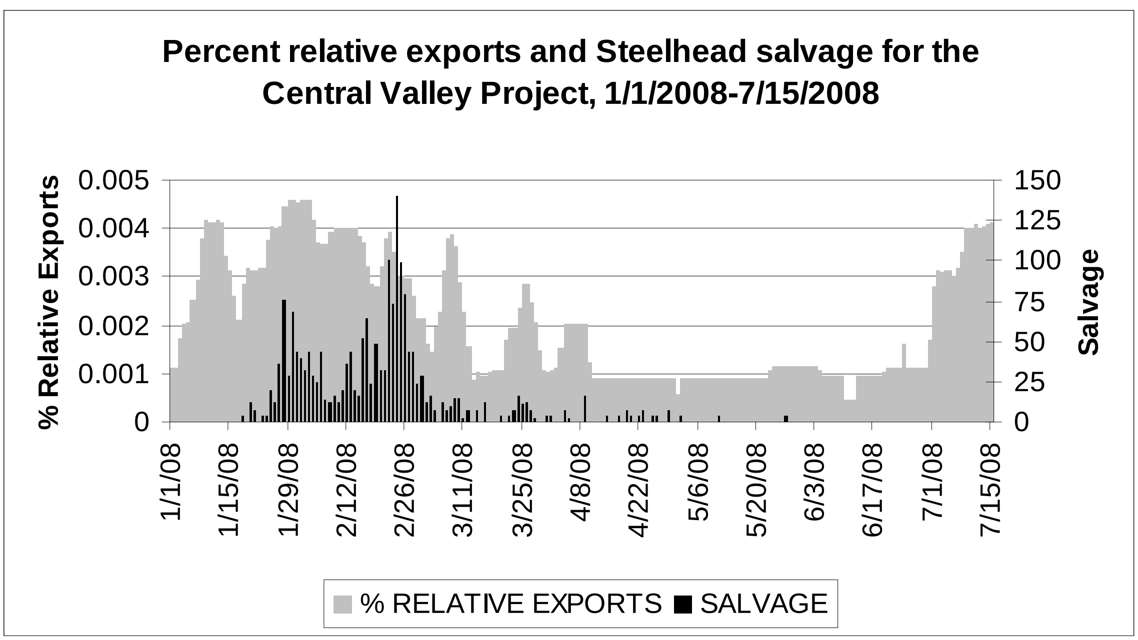


Figure 3-7. Percent relative exports and splittail salvage for the State Water Project, January 1–Aug. 15, 2008

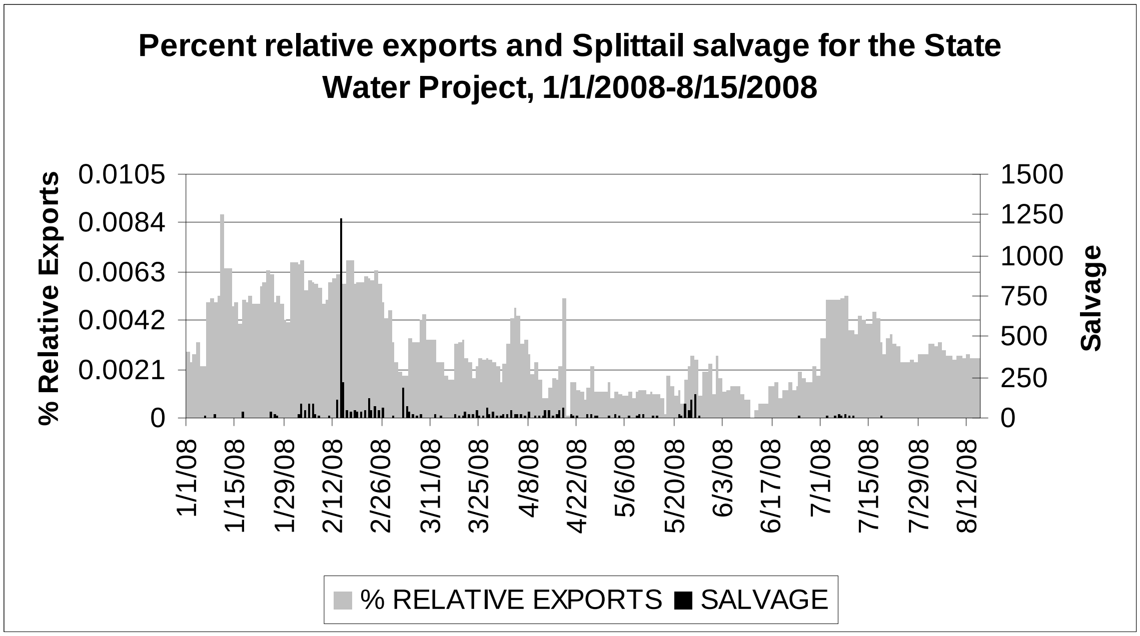


Figure 3-8. Percent relative exports and splittail salvage for the Central Valley Project, January 1–August 15, 2008

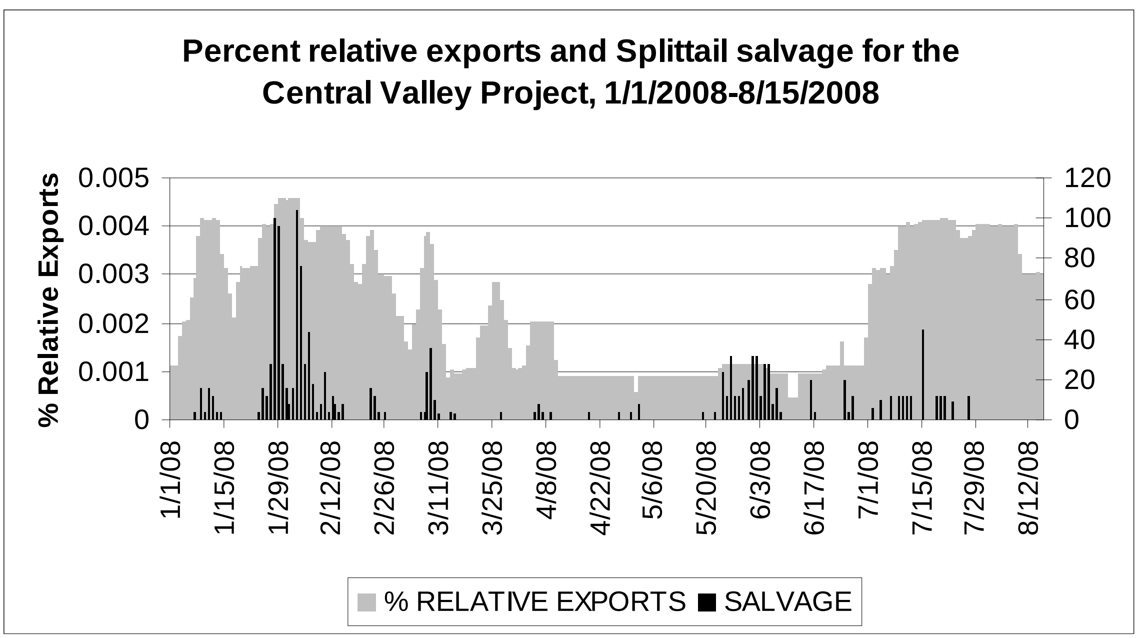


Figure 3-9. Percent relative exports and longfin smelt salvage for the State Water Project, January 15–June 15, 2008

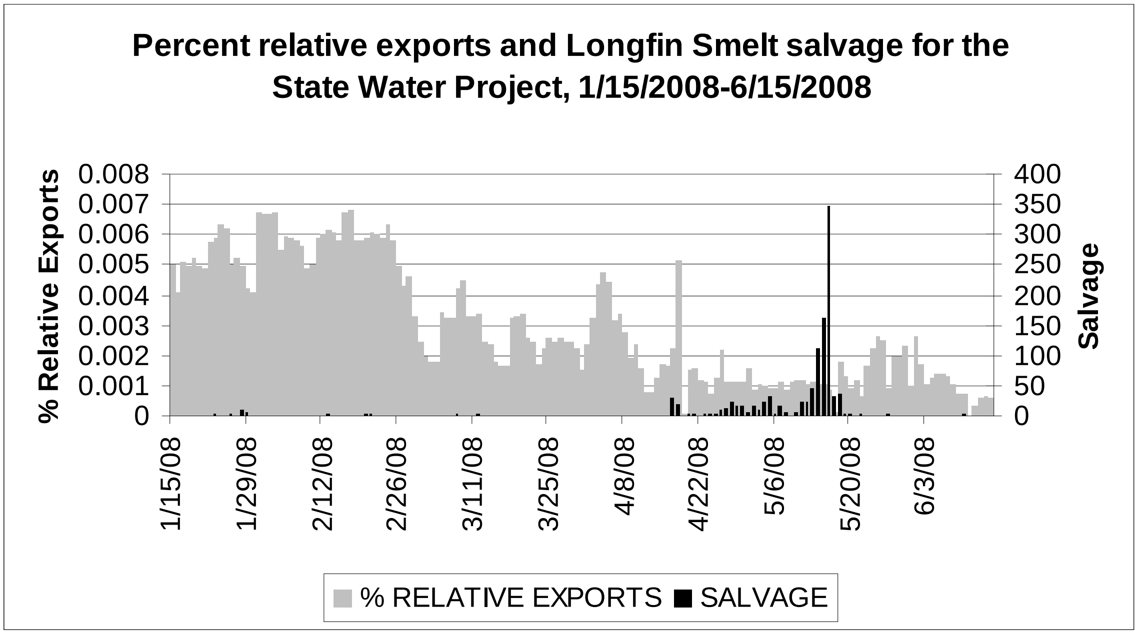


Figure 3-10. Percent relative exports and longfin smelt salvage for the Central Valley Project, January 15–June 15, 2008

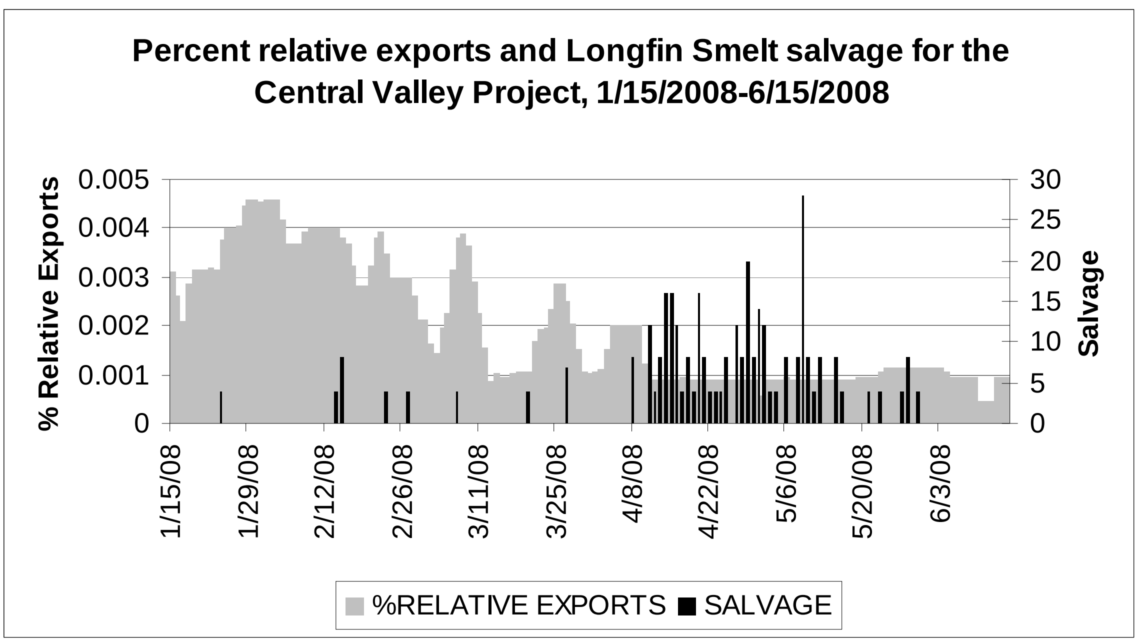


Figure 3-11. Percent relative exports and Delta smelt salvage for the State Water Project, January 5–July 10, 2008

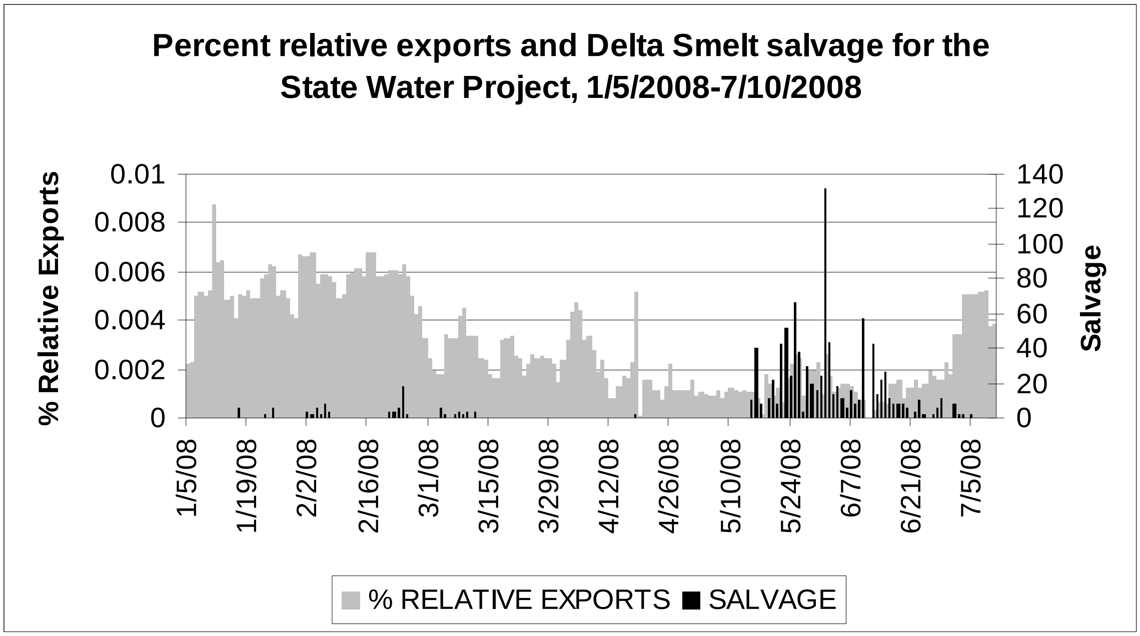
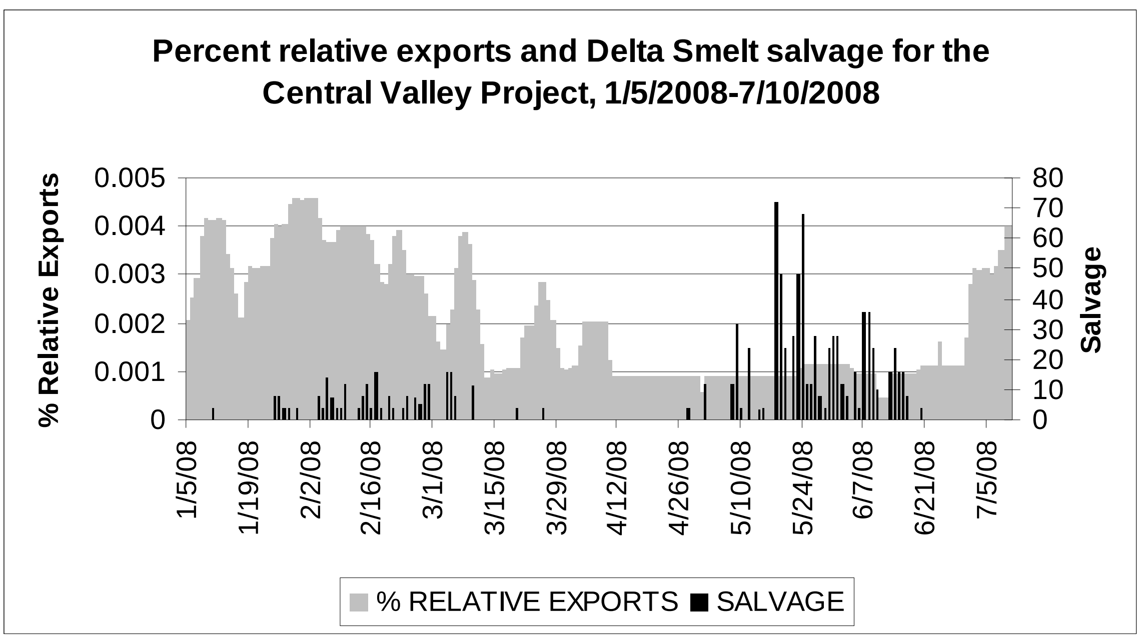


Figure 3-12. Percent relative exports and Delta smelt salvage for the Central Valley Project, January 5–July 10, 2008



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Chapter 4. Swainson's Hawk Survey and Monitoring, 2008 Construction Season

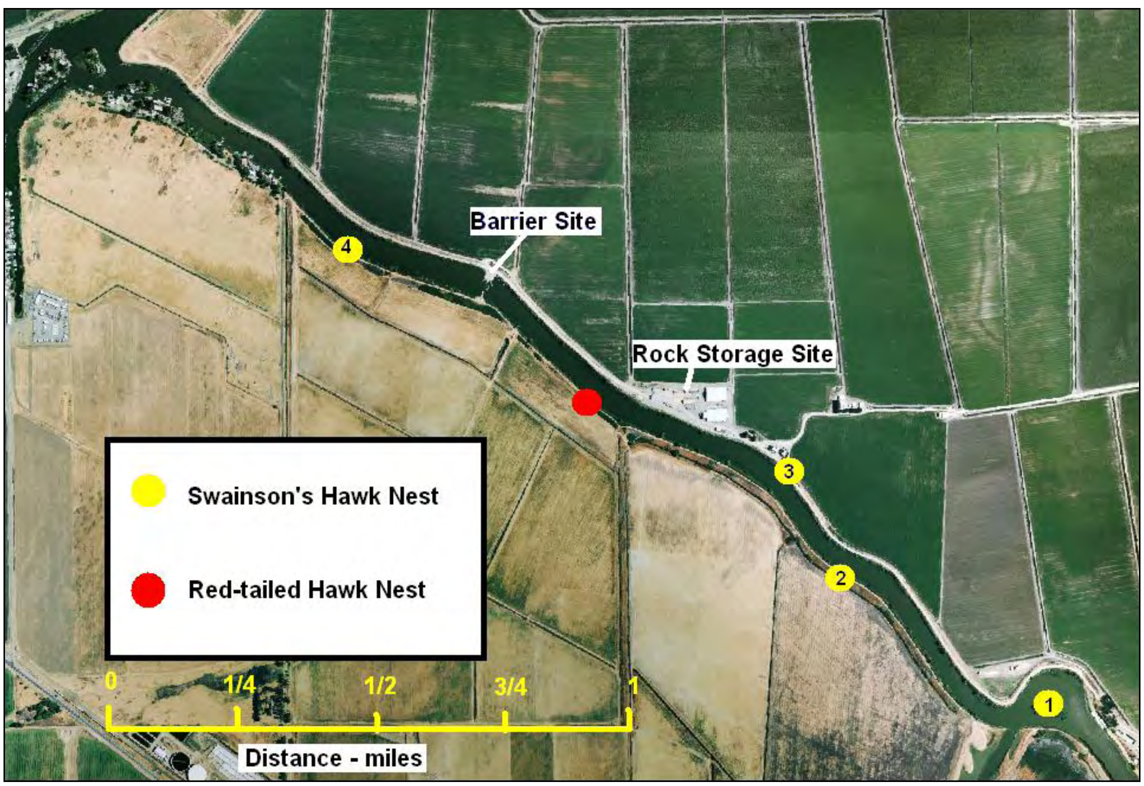
Swainson's hawk surveys were initiated by a DWR biologist at the temporary barrier construction and storage sites in the week of April 14 for the 2008 construction season. Surveys, construction monitoring, and post-construction monitoring continued through the first week of July 2008.

Old River at Tracy Barrier

The first barrier constructed in 2008 was the ORT barrier, which was initiated May 12 and completed June 4. DWR staff and construction personnel participated in an environmental education session the morning of May 12 at the rock storage site for the ORT barrier.

On April 22, there had been 4 active Swainson's hawk nests and 1 active red-tailed hawk nest near the barrier and rock storage sites (see Figure 4-1). By May 5, Swainson's hawk nest No. 3 and the red-tailed hawk nest had failed. This occurred at least a week prior to the initiation of construction at the barrier site. On May 12, the red-tailed hawks were building a new nest slightly upstream of their old nest; they appeared to give up on the second nest 3 days later, though they were frequently observed in their nest territory. The Swainson's hawk pair that failed remained in the nest territory until May 5 but was not observed after that. On May 20, a Swainson's hawk was observed in incubation position at nest No. 2, but by May 27 that nest had failed.

Figure 4-1. Raptor nests at ORT barrier site



Both of the remaining nests, No. 1 and No. 4, hatched 2 young, which were observed on June 16. On July 7, 1 well-developed Swainson's hawk nestling was observed on nest No. 1. It is presumed to have fledged. Two pre-fledged Swainson's hawk young were observed on nest No. 4, and those are presumed to have fledged as well.

It is unlikely that any of the 5 pairs of nesting raptors were affected by construction activities. Of the 3 nests that failed, 2 failed before construction began, and the last was about 0.5 mile from the construction zone, which makes failure from construction disturbance unlikely. Additionally, the most successful nest, nest No. 4 (which fledged 2 young), was closest to the construction activities, and nest No. 1, which only fledged 1 of 2 chicks that hatched, was well outside the construction disturbance zone. The more likely explanation is that 2008 was a poor prey year for these birds. The exception is the Swainson's hawks at nest No. 3, which may have abandoned the nest because of local disturbance; that nest was in a relatively small tree immediately off the road in a location frequented by fishermen. It was surprising that the hawks had chosen that location.

Grant Line Canal Barrier and Accessory Areas

Barrier Site

Construction on the GLC barrier was initiated on May 19, 2008, and completed on June 2. An environmental education session was provided to construction personnel at the start of construction at that site.

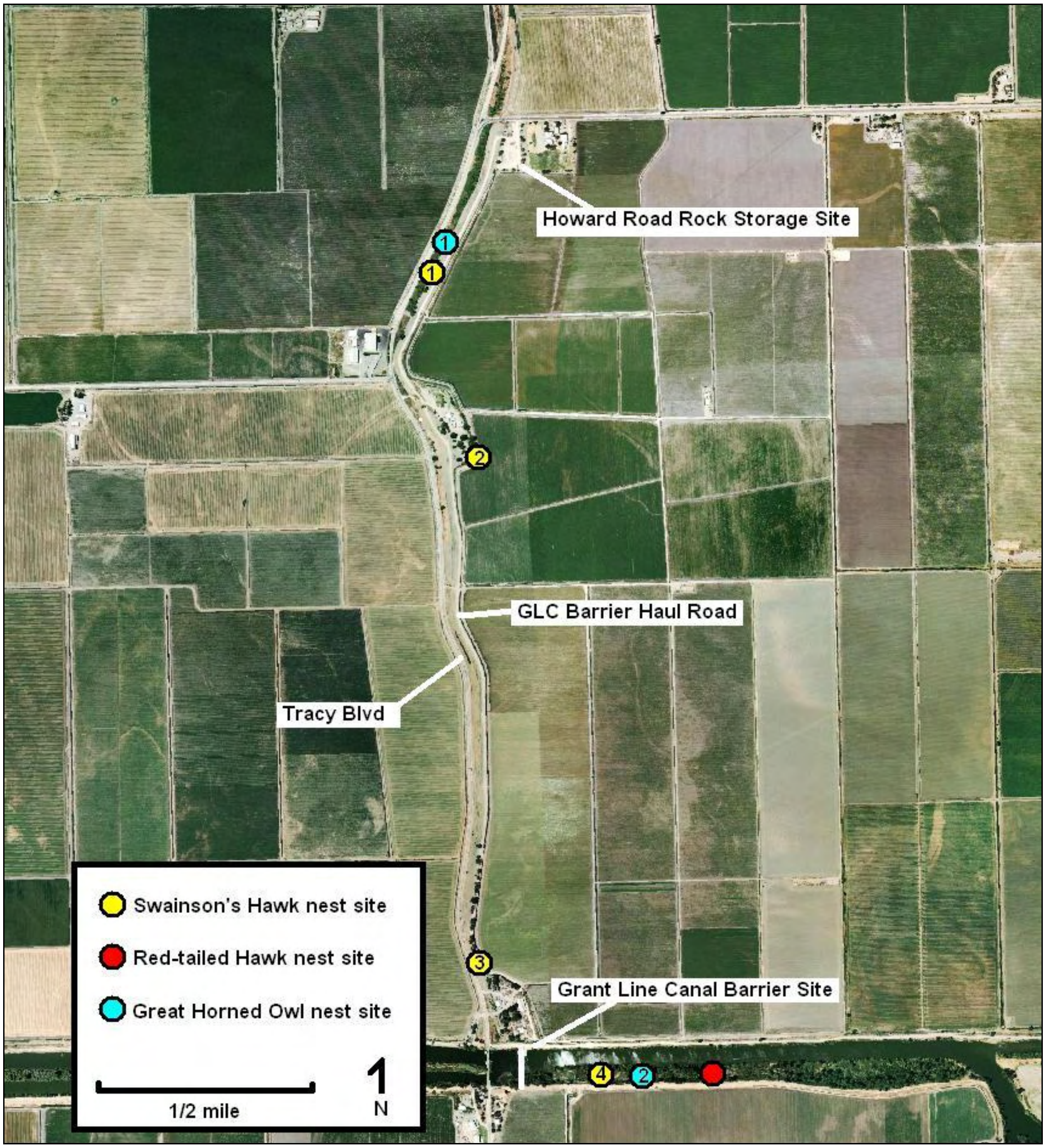
Four pairs of raptors were observed near the barrier site (Figure 4-2); 3 will be referred to as "barrier nests," and 1 will be described in the section below titled "Haul Road between Rock Storage Site and Barrier Site." Swainson's hawk nest No. 4 was on the south side of Grant Line Canal approximately 300 yards east (upstream) of the barrier site. A great horned owl nest was located approximately 200 yards east of the Swainson's hawk nest, and a red-tailed hawk nest was observed about 300 yards east of the great horned owl nest. It is not unusual for these different raptor species to nest in close proximity to each other.

Both the great horned owls and the red-tailed hawks fledged 2 young each. The Swainson's hawk nest failed. Adults were observed tending the nest and displaying typical behaviors through May 29. Both adults were at the nest on that day, but no chicks were observed, which is an indicator that the nest failed, because by that time they should have been at least a week old and easily observed. By June 9, no birds were observed on the nest.

Haul Road between Rock Storage Site and Barrier Site

Four raptor nest sites were observed along the haul road between the Howard Road rock storage site and the GLC barrier site: 3 Swainson's hawk nest sites (2 with nests) and 1 great horned owl nest. The great horned owls fledged 1 young. Swainson's hawk nest No. 1 failed by May 5, though birds had been observed in incubation position prior to that date.

Figure 4-2. Raptor nest sites at the GLC barrier site and accessory facilities



Swainson's hawk nest No. 2 in the farmyard off the road was observed only once before the leaves on the tree and distance to the nest made it impossible to see; the nest tree was on private property and not accessible. The adults remained active in the area through the nest season and are presumed to have fledged young. No nest was confirmed at nest site No. 3, though adults were observed there throughout the nesting season. A pair of Swainson's hawks had been occupying that territory for a number of years without nesting, and the same situation was assumed to be the case for 2008.

Howard Road Storage Site

No raptor nests were observed in close proximity to the rock storage site.

There was no evidence that the GLC barrier construction activities affected the nesting Swainson's hawks in the area. Swainson's hawk nest No. 1 failed prior to the initiation of construction. The

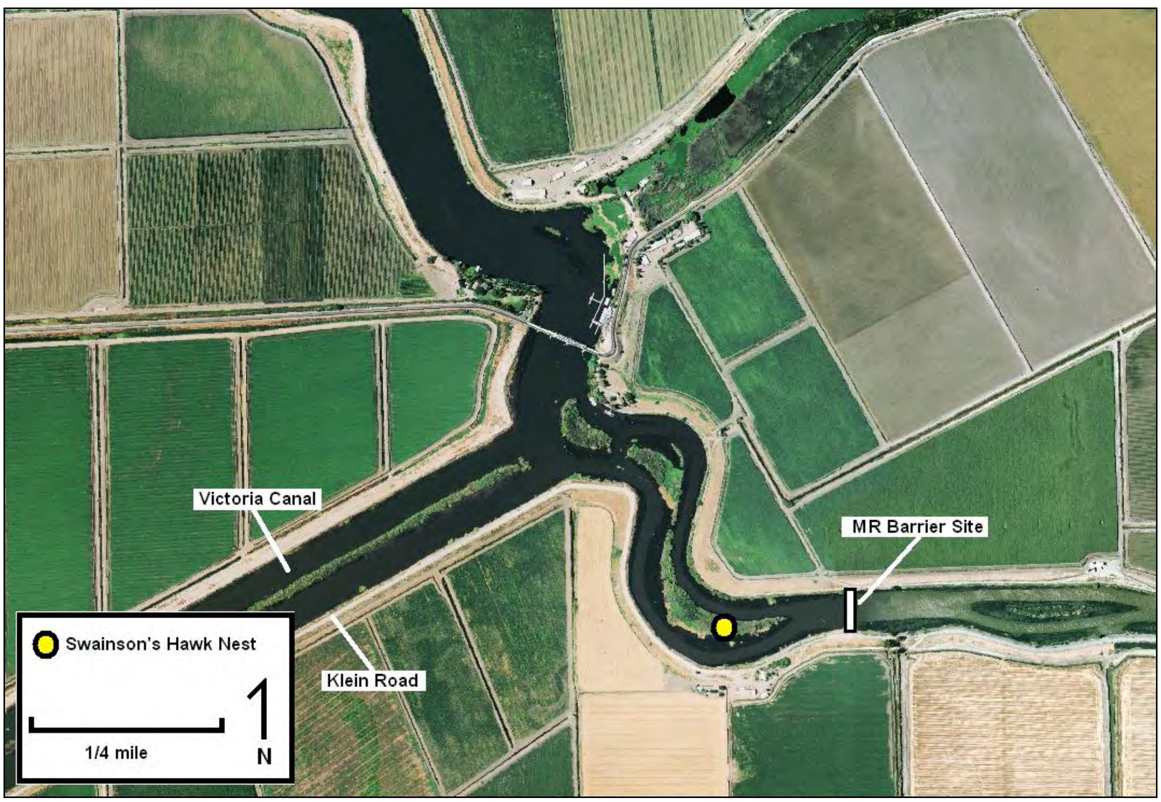
Swainson's hawks at nest site No. 3 apparently never constructed a nest, which would have been done well in advance of the initiation of construction. Although Swainson's hawk nest No. 4 failed during the construction window for the barrier, the nest was 300 yards from the construction zone and well-buffered from the disturbance. Additionally, the pair showed no interest in the construction activities, displayed typical nesting behaviors, and remained at the nest through the entire construction window.

Middle River Barrier

Construction on the MR barrier was begun on May 20 and completed in 2 days. No environmental education session was given at this barrier site because the construction personnel working at this site had attended the presentation at the ORT barrier site and the environmental concerns at each site were similar, though less so at the MR barrier site because of the very short construction window.

Only 1 raptor nest was observed in close proximity to the MR barrier site, a Swainson's hawk nest (Figure 4-3). The female of the pair laid egg(s) between May 1 and May 5 and hatched 1 young. The young was well-developed and close to fledging on July 7, the last date the nest was checked, and the nest site was presumed to be successful.

Figure 4-3. Raptor nests at the MR barrier site



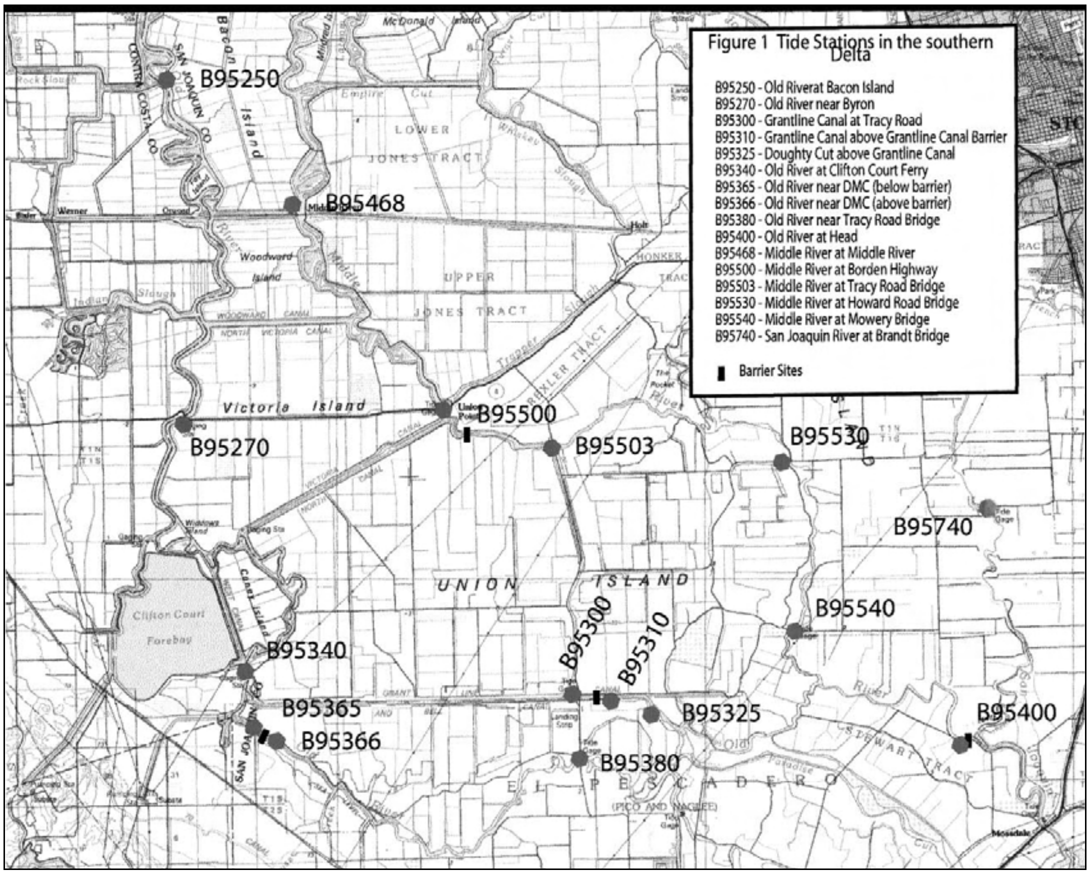
Head of Old River Barrier

The HORB was not installed in spring 2008. A survey for Swainson's hawks was done in the area around the HORB site on April 23 but then was discontinued because there would be no impacts from construction at that site.

Chapter 5. Water Elevations

The 2008 water elevation monitoring program included operation and maintenance of 16 tide gauging stations near the barriers, as shown in Figure 5-1. The 2008 monitoring program covers the period from January 2008 through December 2008, where stage is monitored at various stations with remote sensors.

Figure 5-1. Tide stations in the southern Delta



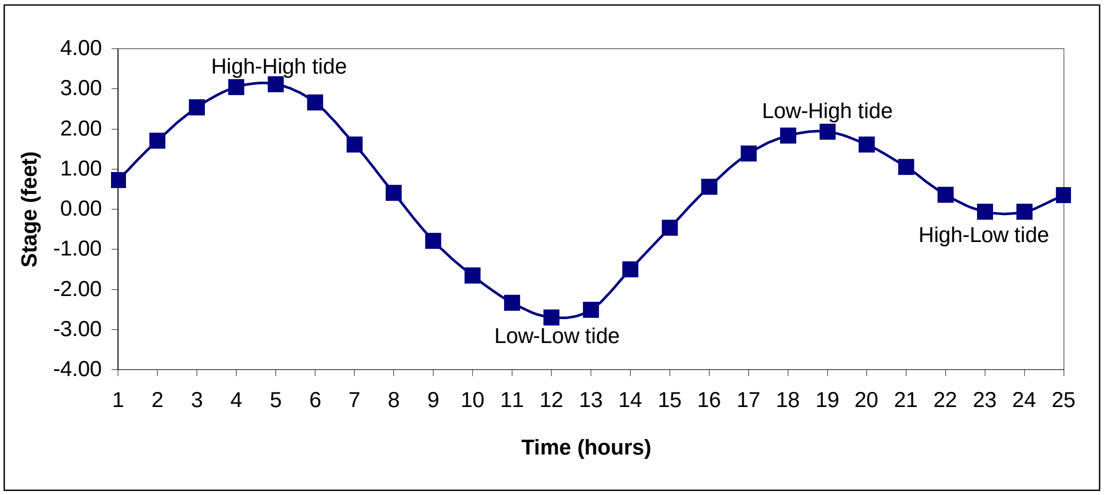
Instrumentation recorded water surface elevation daily at 15-minute intervals. Later, the data records were retrieved and downloaded to a computer for subsequent analysis.

Data collected at these stations were used to determine effects of the barriers on the water surface elevations and circulation patterns in the south Delta. Circulation patterns are estimated using the water surface elevation data as an input to the hydrologic mathematical model (DWR’s DSM2). Results of the model can be found elsewhere in this report.

Tides along the Pacific coast exhibit a cycle of 2 high and 2 low tides over an approximately 25-hour period (Figure 5-2). These cycles vary in height throughout the day. Two elements make up a typical tidal curve.

- The tidal range is the difference between the highest and lowest tidal elevations.
- The daily inequality is the difference between the heights of successive high or low tides and the time between corresponding high or low stands of sea level.

Figure 5-2. Tide stage variation along the Pacific coast over a 25-hour period



A biweekly pattern of spring and neap tides is overlaid on top of the daily pattern. Additional patterns occur at longer intervals throughout the year.

Typically, farmers in the south Delta encounter pumping difficulties due to low water elevations during the irrigation season. One objective of the ORT, MR, and GLC barriers is to improve water elevations for agricultural diversions. This goal is achieved by installing barriers with culverts that restrict flow in the downstream direction during ebb (receding) tides, resulting in increased water levels upstream of the barrier. During periods of increasing (flood) tides, the open flap gates allow flow in the upstream direction. Sometimes during high flood tides, water also flows over the barrier, thereby further increasing water level upstream of the barrier. The increasing tide replenishes water being lost or diverted for agriculture and will maintain higher water levels during the next receding tide.

The agricultural barriers are constructed from rock with flap-gated culverts to allow flow in the upstream direction. Design of the 3 barriers mentioned above varies slightly due to differences in upstream channel geometry.

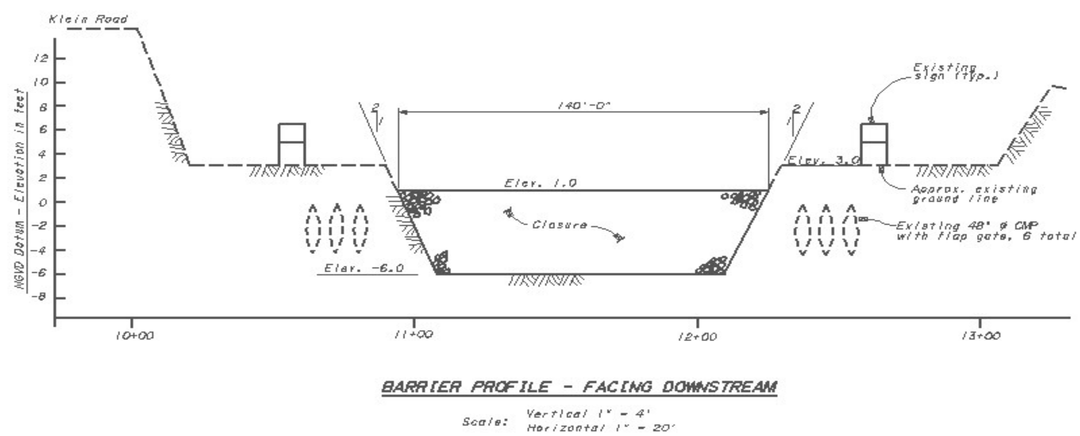
The following are highlights of barrier installation effects:

- At low tide, water surface elevation upstream of the barrier is raised, but the elevation downstream follows the tidal cycle.
- High tide water surface elevations upstream of the barrier are slightly delayed until the tide overcomes the height of the barrier.
- During ebb tides, culvert flap gates seal and retain water behind the barriers.

Middle River Barrier

The MR barrier abutments are constructed to an elevation of +3.0 feet National Geodetic Vertical Datum (NGVD) and has six 48-inch-diameter culverts. The center weir section is 140 feet wide and constructed to an elevation of +1.0 foot NGVD (Figure 5-3). The center portion of the barrier is removed seasonally, while the culverts and the abutments remain in place year-round. (Three culverts are located in the north abutment, and 3 culverts are located in the south abutment.) Culvert replacement due to deterioration and old age is scheduled for 2009.

Figure 5-3. MR barrier profile

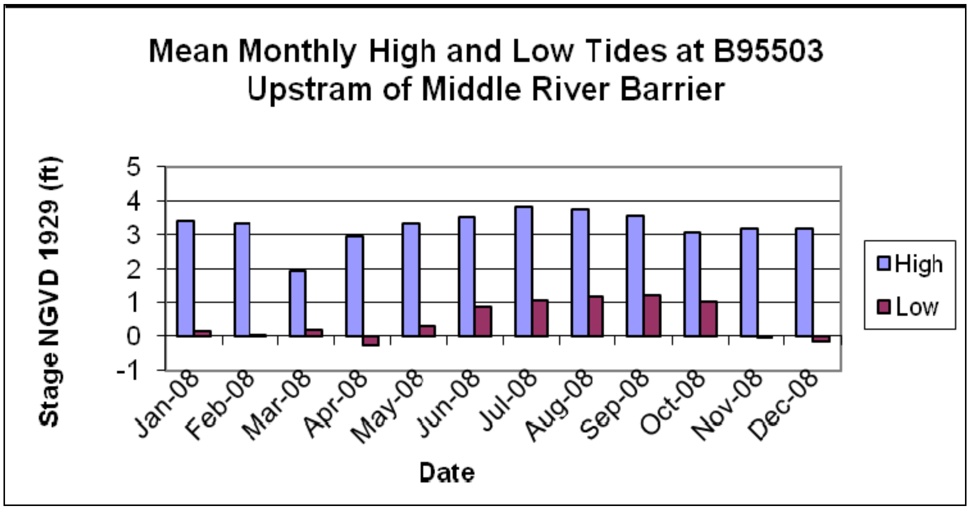


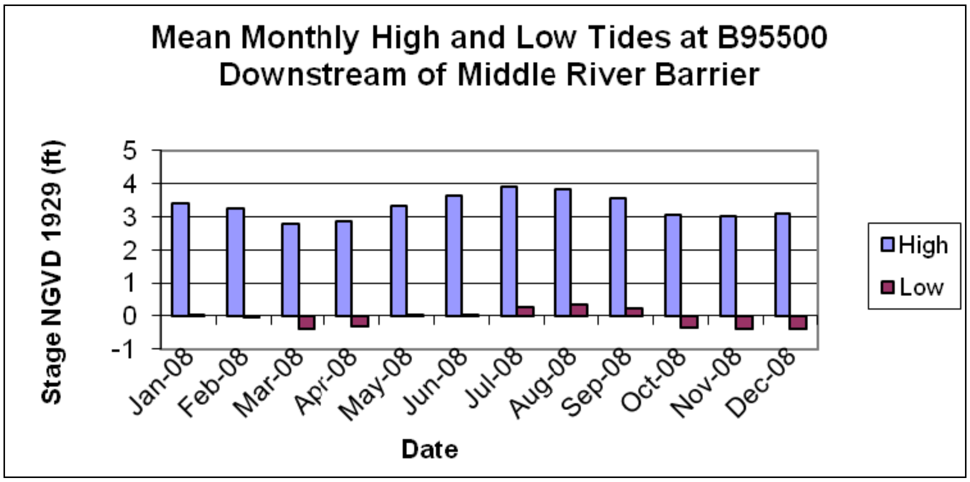
The installation of the MR barrier started on May 19, 2008, the closure was accomplished by May 21, and the complete installation was accomplished by May 23. The flap gates were tied open until July 3, 2008, when the order was issued to untie them. The flap gates were tidally operational from early July until November, when the barrier removal began. For the 2008 operation, the MR agricultural barrier was allowed to remain until November 5, 2008. The MR barrier removal work began on November 5, the barrier was breached on November 5, and construction completed on November 9.

Water level monitoring was conducted at 2 nearby tide recording stations: B95500, downstream of this barrier at Borden Highway (Highway 4); and B95503, just upstream of the barrier.

Figure 5-4 shows the mean monthly high tides and mean monthly low tides upstream and downstream of the Middle River barrier from January 2008 to December 2008. The barrier was in operation between late May and early November 2008. Figure 5-4 shows mean monthly low water levels upstream of the barrier: 0.86 foot in June, more than 1 foot in August and September, and 1 foot in October.

Figure 5-4. Water levels upstream and downstream of MR barrier





Old River at Tracy Barrier

The ORT barrier abutments are constructed to an elevation of +4.0 feet NGVD and have nine 48-inch-diameter culverts. The center weir section is 75 feet wide and constructed to an elevation of +2.0 feet NGVD (Figure 5-5). The entire barrier structure is removed yearly.

The installation of the ORT barrier started on May 12, 2008; it was closed by June 4, and the installation was completed by June 19. The flap gates remained tied open from the beginning of installation until July 9, 2008, at which point 6 of the 9 flap gates were operating tidally while the other 3 remained tied open to allow improved circulation and possible improved water quality into Old River. This scenario of having 6 flap gates operating tidally and 3 tied open remained until August 4, 2008, when 3 additional flap gates were tied open for a total of 6 culverts tied open for water quality purposes. These additional open culverts helped improve circulation particularly while spring tide was occurring and without any adverse impact to water levels. Two days later, the additional 3 flap gates that were tied open were released back to tidal operation, with a resulting configuration of 3 flap gates tied open and 6 flap gates tidally operated. The decision behind this move was to protect water levels ahead of the approaching neap tide at the end of that week. This configuration was sustained until September 17, 2008, when the 3 culverts with their flap gates tied open were released, making all 9 flap gates tidally operating through Monday, September 29, 2008, when 3 flap gates were tied open to allow more circulation upstream of the barrier on Old River and improve water quality in the area. The ORT barrier was breached on November 4, 2008; the in-water work was completed Sunday, November 16, and the complete removal was achieved by November 25.

Water level monitoring is conducted at 2 nearby tide stations: B95365, downstream of the ORT barrier; and B95366, upstream of the barrier. In 2008, the station on the upstream side of the barrier performed well and reported good data; the downstream data recorder did equally well. Figure 5-6 shows mean low and high water surface elevation for this station upstream and downstream of the ORT barrier from January 2008 to December 2008. Figure 5-6 shows an increase in mean monthly low water levels on the upstream side of the barrier of approximately 0.75 foot in June and more than 2 feet for the period July through October. This is a positive effect for irrigators.

Figure 5-5. ORT barrier profile

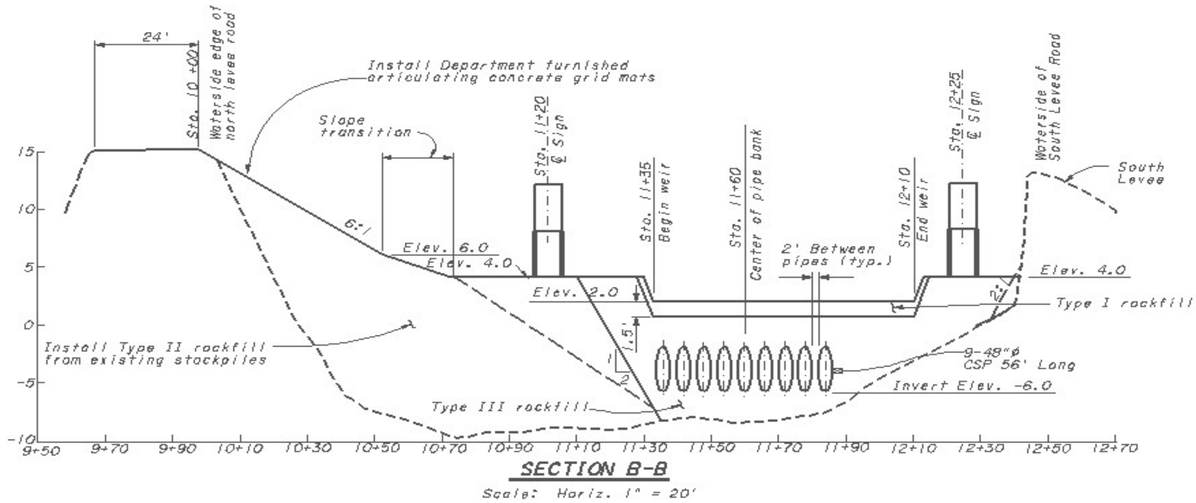
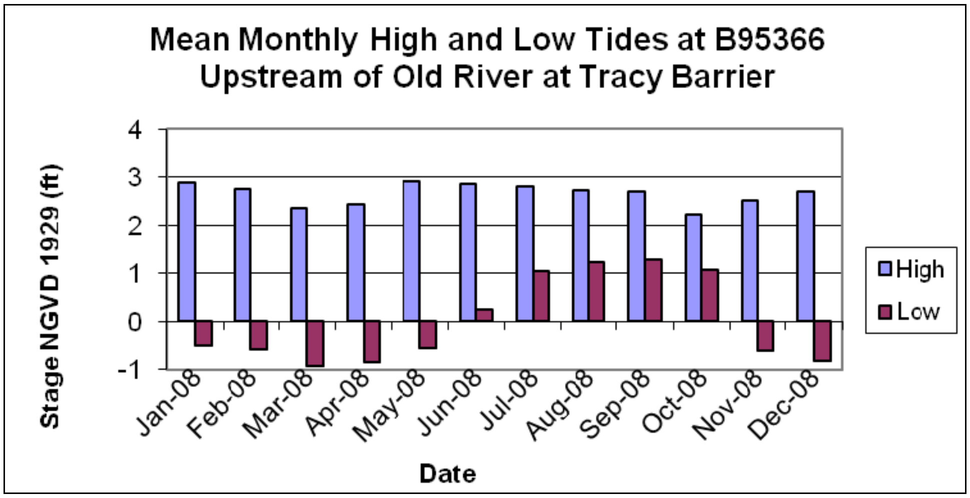
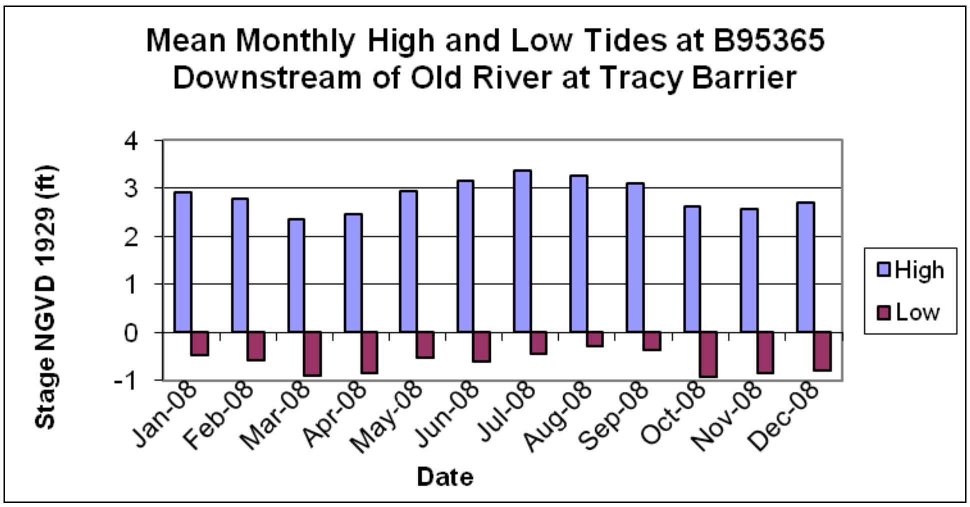


Figure 5-6. Water levels upstream and downstream of ORT barrier





Grant Line Canal Barrier

The GLC barrier is constructed to an elevation of +4.0 NGVD and has six 48-inch-diameter culverts at the southern abutment of the barrier. The center weir section is 140 feet wide and constructed to an elevation of +1.0 foot NGVD. Figure 5-7 shows the culverts, fish passage weir, and southern abutment of the GLC barrier, which to remains in the channel year round.

In 2008, construction of the northern abutment of the rock barrier started on May 19; it was partially closed (construction of the boat ramp) by June 2, 2008. Work on closing the middle portion of the barrier was completed by Thursday, June 26, 2008. The flashboards in the fish flashboard structure on the south side of the Grant Line Canal were removed to allow Delta Smelt passage, allowing a minimum depth of 6 inches of water to pass over the barrier during the lower high tide event. In the Fall this structure also ensures that adult Chinook salmon that have strayed into the south Delta can pass over the barriers on their way upstream.

The barrier removal work began on November 8, 2008; the breach was accomplished by November 11, and the barrier was fully removed by November 24. Water level monitoring is conducted at 2 nearby tide recording stations: B95300, just downstream of the barrier; and B95325, at Doughty Cut upstream of the barrier.

Figure 5-7. GLC barrier profile

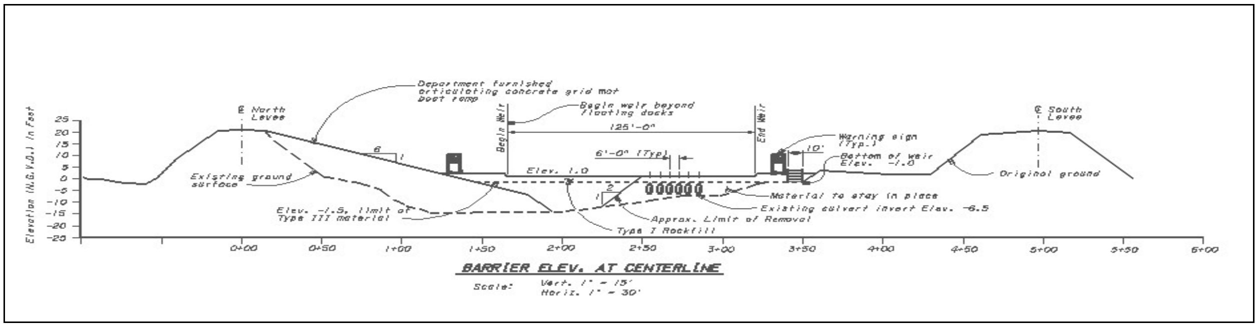
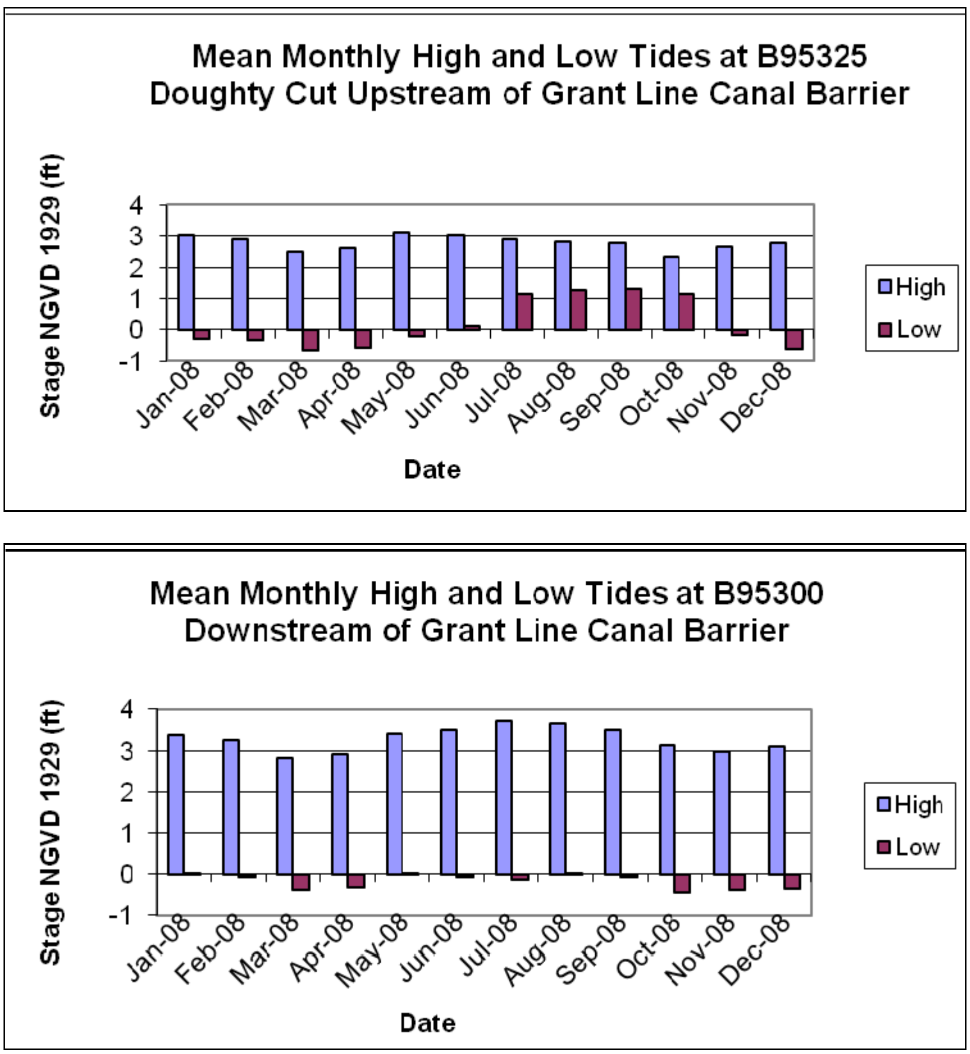


Figure 5-8 shows stages upstream and downstream of the GLC barrier from January 2008 to December 2008. Figure 5-8 shows an increase in mean monthly low water levels on the upstream end of more than 2 feet for the period stretching from July through the end of October.

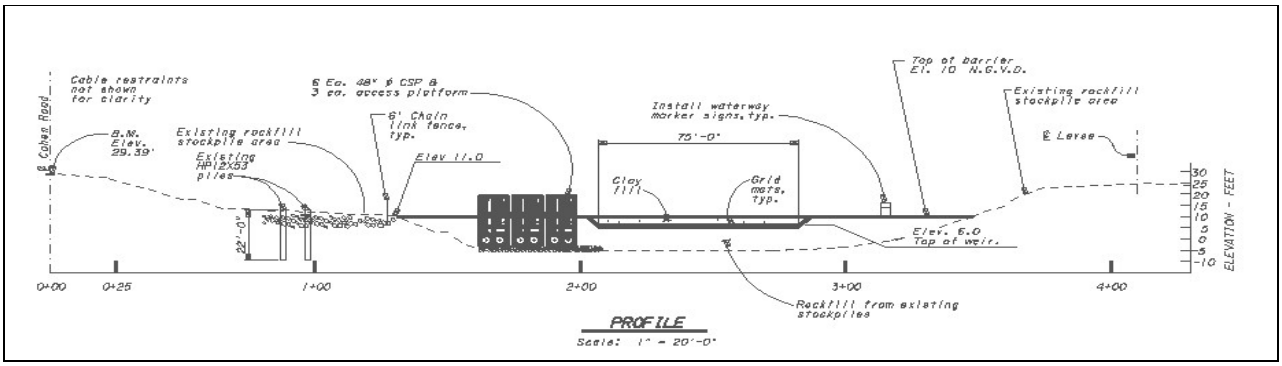
Figure 5-8. Water levels upstream and downstream of GLC barrier



Head of Old River Barrier

The HORB is designed as a fish barrier to prevent San Joaquin River Chinook salmon smolt from migrating down through Old River toward the CVP and SWP export facilities. The spring HORB was originally designed to withstand a San Joaquin River flow of about 3,000 cfs. Through the years, the design and installation of the HORB has been revised on several occasions to accommodate different needs. In previous years, the barrier design included 2 versions. A “low-flow” barrier (Figure 5-9) built to a height of 10 feet mean sea level (MSL) when San Joaquin River target flows are below 7,000 cfs. A “high-flow” barrier built to a height of 11 feet MSL for San Joaquin River target flows of 7,000 cfs and above was placed, along with additional material, to raise the abutments to 13 feet MSL. Both barrier versions are equipped with six 48-inch-diameter operable culverts and an overflow weir backfilled with clay. In 2008, the spring HORB was not installed, pursuant to a December 14, 2007, interim remedial order by US District Court Judge Oliver Wanger.

Figure 5-9. Spring HORB profile



The fall HORB installation started on October 1, 2008. Closure was achieved on October 16, and it was notched and completed on the same day. Barrier removal started on November 3, 2008; it was breached on the same day. Complete removal was accomplished by November 9, 2008. The fall HORB was constructed to an elevation of +4.0 feet NGVD and had six 48-inch-diameter culverts (Figure 5-10).

Figure 5-11 shows mean monthly high and low water levels in Old River at head approximately 1,000 yards below the confluence for the period extending from January 2008 to December 2008. The mean monthly low water level for the fall HORB installation was a little over 1.5 feet NGVD, and it was recorded during October 2008.

Figure 5-12 shows water levels at Tom Paine Slough (TPS) above the mouth, above the intake structure, and at Pescadero Pump Plant #6.

Station B95420 TPS above the mouth reported that the mean monthly low level was below zero for the months of January through April and was above 0.5 foot during the month of May. In June, the mean monthly water level dipped below 0.5 foot. For the period from July to October, it was above 1 foot. During the months of November and December, the water level was below zero MSL.

Station B95421 TPS above the intake structure reported a mean monthly low level of 1 foot during the months of April through June and approximately 1.5 feet for the July–October period. In November a mean monthly low level of a bit more than 1 foot was recorded, and in December the mean monthly low level was above 0.5 foot.

Station B95425 TPS at Pescadero Pump Plant #6 showed a mean monthly low of a little over 1 foot during the month of April. The highest was observed in September, a value of more than 1.5 feet NGVD. For the reminder of the year, the station was experiencing problems due to equipment malfunctioning, and no data were recorded.

Figure 5-10. Fall HORB profile

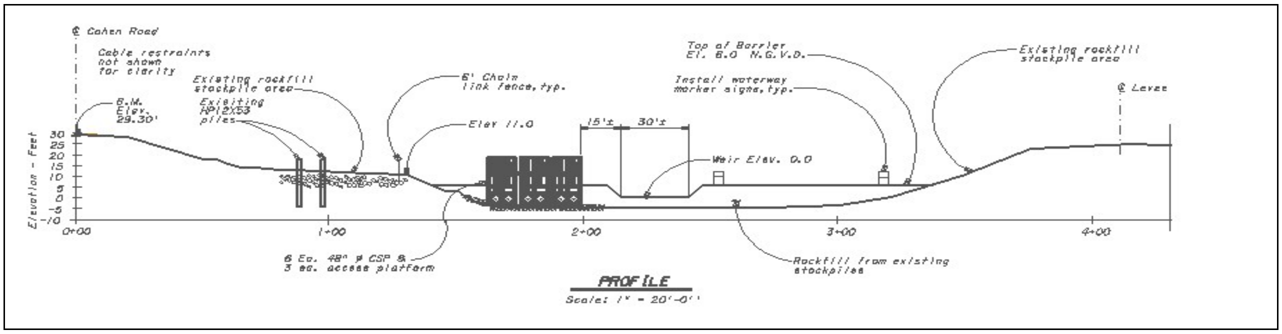


Figure 5-11. Water levels downstream of HORB

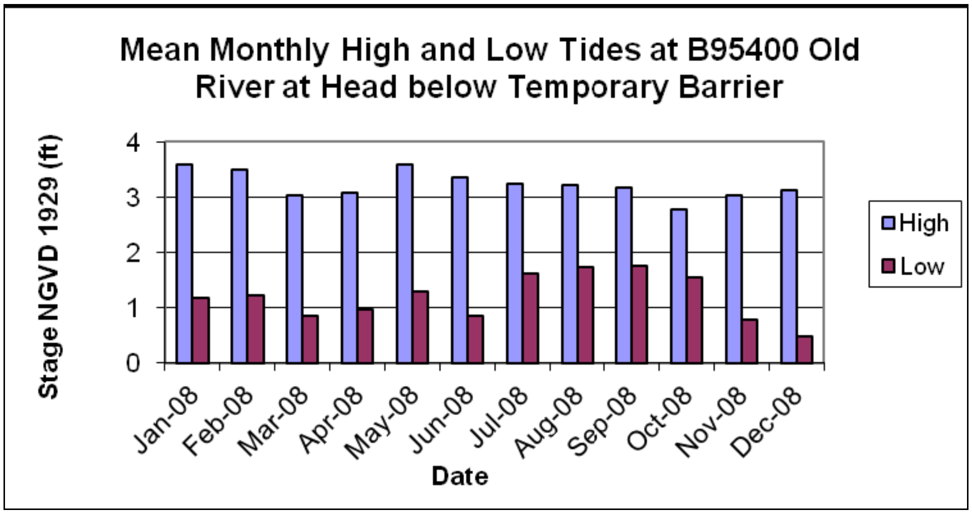
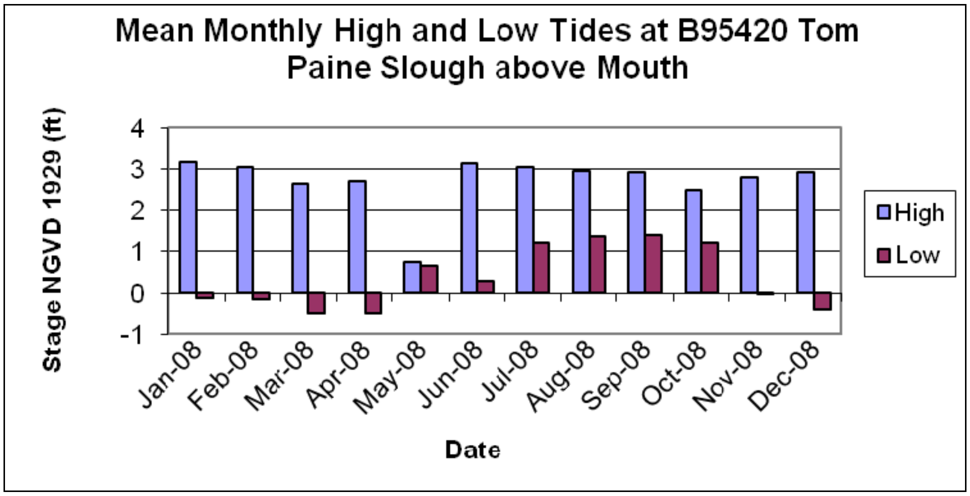
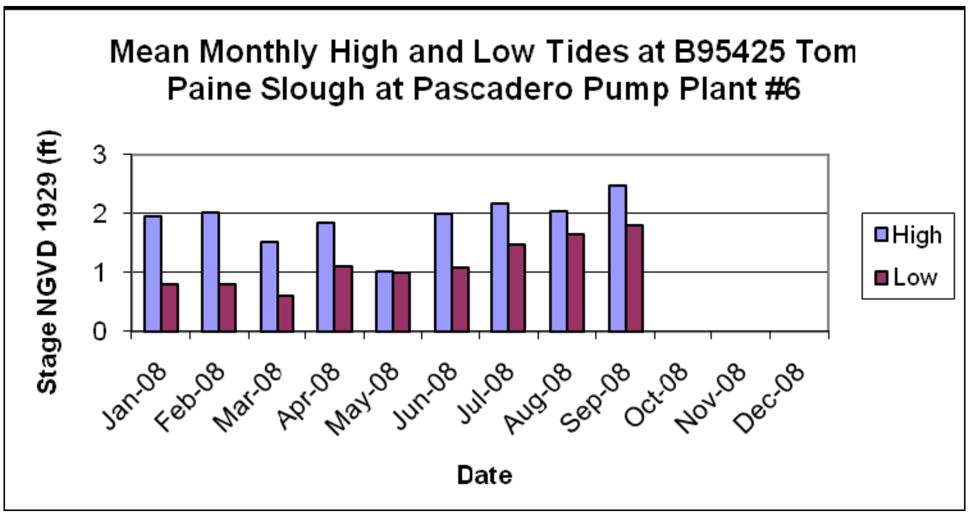
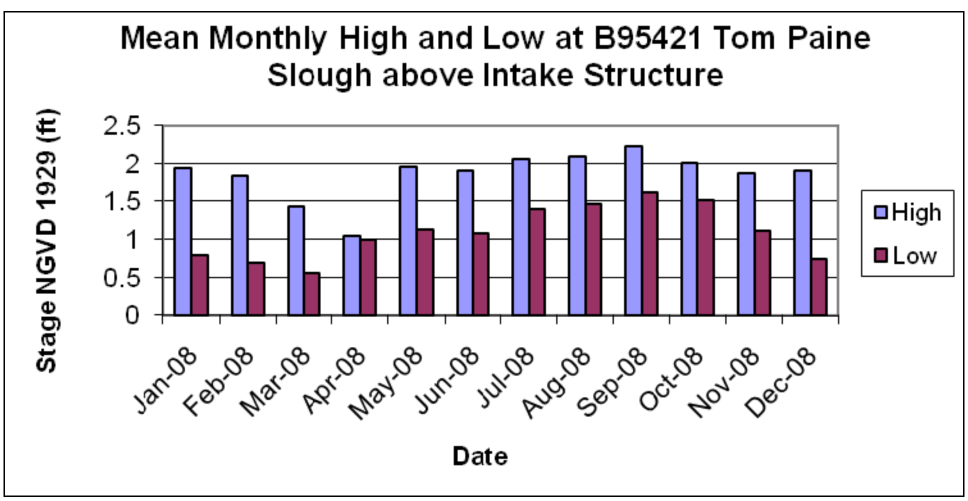


Figure 5-12. Water levels at Tom Paine Slough above mouth, at Pump Plant #6, and above the intake structure







Chapter 6. South Delta Water Quality

Introduction

DWR has been monitoring water quality as part of the south Delta TBP since 1991 to elucidate water quality conditions in the south Delta that may be affected by temporary barrier installations and operations. In 2008, DWR continued its south Delta water quality sampling program, which consists of 2 components: bimonthly discrete sampling and continuous sampling. The information collected by this program is required to comply with a CWA Section 401 water quality certification issued by the Central Valley Regional Water Quality Control Board. For detailed information on the South Delta Improvements Program and the TBP, visit DWR's Bay-Delta Office Web site at http://baydeltaoffice.water.ca.gov/sdb/.

Historically, discrete sampling was conducted on a weekly basis at 10 locations to monitor physical and biological constituents, as well as nutrients. The objective of the discrete program was to monitor the effects of barrier operations on water quality. To meet this objective, discrete sampling commenced 2 weeks before the barriers were installed and did not conclude until 2 weeks after all the barriers were removed. Sampling was conducted every Tuesday morning to target the time when DO concentrations tend to be lowest.

In 1998, DWR's Central District initiated a pilot program to test the viability of establishing permanent multi-parameter water quality stations in the south Delta to continuously monitor water temperature, pH, DO, specific conductance, and turbidity. This program was established to better understand barrier installations in accordance with the following: 1) determining the feasibility of collecting reliable time-series water quality data; 2) developing an understanding of dynamic water quality conditions in a tidally influenced system; and 3) establishing and maintaining long-term continuous data records in the south Delta for analysis.

This continuous water quality monitoring program began with two stations: Old River at the Tracy Wildlife Association and Middle River at Howard Road. The time-series data generated from these two sites was found to be reliable, accurate, and precise when compared with calibration standards and field data. The success of the pilot program resulted in the decision to expand the continuous monitoring program. The expansion was designed to complement the existing discrete stations and resulted in employing a multi-parameter instrument at each of the 10 discrete monitoring locations. To meet this objective, additional continuous stations were installed between 2000 and 2006. With the installation of multi-parameter instruments at the discrete locations by 2006, the weekly DO sampling was terminated, and monitoring of biological constituents and nutrients was changed from weekly to bimonthly.

In 2005, a South Delta Permanent Barriers Project monitoring proposal was drafted that included the implementation of 3 new continuous multi-parameter water quality stations. The proposed station locations were Grant Line Canal near Old River, Victoria Canal, and Doughty Cut above Grant Line Canal. The water quality instruments at Grant Line Canal near Old River and Victoria Canal were co-located with acoustic Doppler current profiler instruments. The establishment and operation of both instruments at these stations was designed to provide time-series water quality data that could be correlated with time-series flow data. The establishment of a multi-parameter station at Doughty Cut was proposed to document possible improvements to water quality based on permanent barrier operation. All 3 stations also would provide water quality information for the calibration and validation of the DSM2 model for the south Delta.

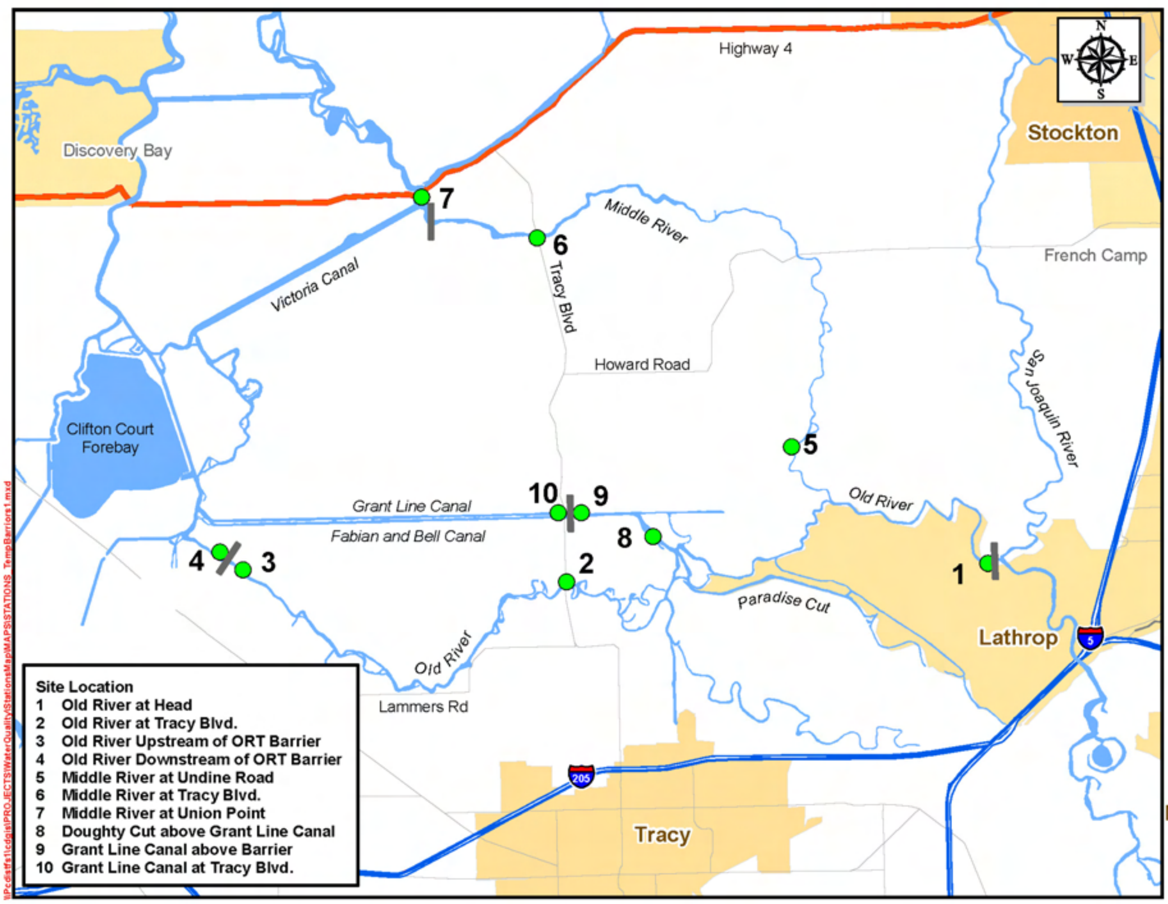
Central District staff installed multi-parameter water quality stations at Doughty Cut above Grant Line Canal in 2006 and at Victoria Canal and Grant Line Canal near Old River in 2007. The data collected at these 3 sites is included in this chapter for data evaluation and analysis purposes.

Materials and Methods

Discrete Monitoring

The discrete monitoring program consists of 10 permanent sampling sites, shown in Figure 6-1. The locations include one on the downstream side of each barrier and one on the upstream side of each barrier, excluding the HORB. Also, additional sites are located further upstream on each of the main river channels (Old River, Middle River, and Grant Line Canal). Sampling of chlorophyll *a*, pheophytin *a*, dissolved ammonia, dissolved nitrite + nitrate, dissolved organic nitrogen, and dissolved orthophosphate was conducted bimonthly from May 14 through December 3, 2008, on Tuesday mornings between 5 a.m. and 9 a.m. at each of these stations.

Figure 6-1. Map of DWR discrete water quality sites in the south Delta



Chlorophyll *a* and pheophytin *a* samples were collected from the top of the water column using a stainless steel container. Water from the container was used to fill a plastic quart bottle at each site. All sample bottles collected were stored in a cooler containing ice packs to preserve the samples at 4 ºC and to keep them out of the sunlight. Immediately after the samples were collected, they were taken to a site in Stockton for filtration. For each sample, approximately 500 mL of water was passed through a 47-mm-diameter glass fiber filter with a 1.0 µm pore size at a pressure of 10 inches of mercury. After filtration, the filters were immediately frozen and transported to DWR's Bryte Laboratory for analysis according to *Standard Methods for the Examination of Water and Wastewater*.

Ammonia, nitrite + nitrate, organic nitrogen, and orthophosphate surface water samples were collected in the field using a stainless steel container. Water from the container was used to fill a plastic quart bottle at each site. All sample bottles collected were stored in a cooler containing ice packs to preserve the samples at 4 ºC. Immediately after the samples were collected, they were taken to a site in Stockton for filtration. The samples were filtered through a 0.45-µm-pore-size membrane filter into a half-pint polyethylene bottle. The samples were then immediately transported to Bryte Laboratory for analysis. A summary of the lab methods for the nutrients measured is shown in Table 6-1.

Table 6-1. Summary of lab methods for the water quality constituents measured at each of the 10 discrete water quality sampling sites.

Constituent	Lab method[a]
Dissolved ammonia	EPA 350.1
Dissolved nitrite+nitrate [a]	Modified Standard Method 4500-NO3-F
Dissolved organic nitrogen	EPA 351.2
Dissolved orthophosphate[1]	Modified EPA 365.1
Chlorophyll *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll
Pheophytin *a*	Standard Method 10200 H, Spectrometric Determination of Chlorophyll

[a] Dissolved nitrite + nitrate and dissolved orthophosphate lab methods modified by DWR Bryte Laboratory.

Data analysis: The use of summary statistics, such as mean, maximum, and minimum are used to compare the data for each constituent shown in Table 6-1 at all 10 discrete stations. Data for each constituent measured is also presented graphically by waterway (Old River, Middle River, and Grant Line Canal).

Continuous Monitoring

DWR collects water temperature (ºC), DO (mg/L), pH, specific conductance (microsiemens per centimeter [µS/cm]), turbidity (nephelometric turbidity units [NTU]), and chlorophyll (micrograms per liter [µg/L]) data in 15-minute intervals. These data are collected at a 1-meter depth by deploying Yellow Spring Instrument (YSI) 6600 sondes. Continuous data is collected at 13 multi-parameter monitoring stations in the south Delta: 4 stations in Middle River, 4 stations in Old River, 4 stations in Grant Line Canal, and 1 station in Victoria Canal. (Figure 6-2 shows site locations.) Station coordinates and the date the station was established are shown below, in Table 6-2. Two continuous monitoring sites were installed in 2007, Grant Line Canal near Old River and Victoria Canal. These stations are operated in conjunction with USGS flow stations and provide real-time data on the California Data Exchange Center (CDEC) (http://cdec.water.ca.gov/). To access data from these stations, select "Real-time Data" from the menu and then enter in the 3-digit station identification code. The code for Victoria Canal is "VCU," and the code for Grant Line Canal is "GLC."

Figure 6-2. Map of DWR continuous water quality monitoring sites in the south Delta

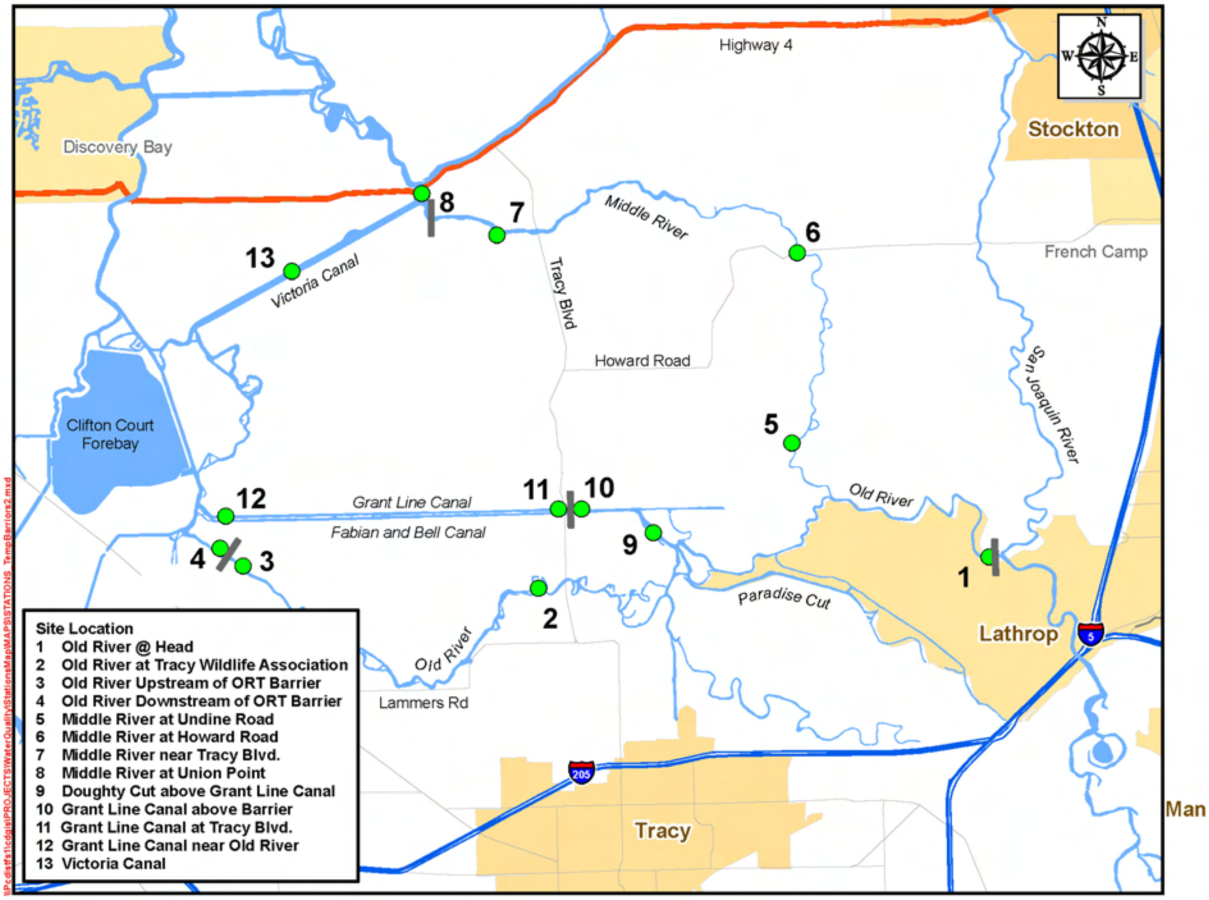


Table 6-2. Continuous monitoring station coordinates and date of establishment

Station	Latitude	Longitude	Date established
Old River near head	37º 49' 09.8"	-121º 21' 36.4"	Jan 1, 2001
Old River at Tracy Wildlife Association	37º 48' 10.1"	-121º 27' 26.7"	Jul 14, 1999
Old River upstream of the ORT barrier	37º 48' 36.9"	-121º 32' 31.9"	Jan 1, 2000
Old River downstream of the ORT barrier	37º 48' 39.5"	-121º 32' 39.9"	Jan 18, 2006
Middle River at Undine Road	37º 50' 02.2"	-121º 23' 08.6"	Jun 4, 2002
Middle River at Howard Road	37º 52' 34.4"	-121º 22' 59.9"	Oct 1, 1999
Middle River near Tracy Boulevard	37º 52' 53.2"	-121º 28' 02.5"	Jan 1, 2003
Middle River at Union Point	37º 53' 26.8"	-121º 29' 18.1"	Feb 23, 2006
Doughty Cut above Grant Line Canal	37º 48' 53.0"	-121º 25' 30.8"	Jun 19, 2006
Grant Line Canal above the GLC barrier	37º 49' 12.7"	-121º 26' 42.1"	Mar 24, 2006
Grant Line Canal at Tracy Boulevard	37º 49' 12.4"	-121º 26' 59.4"	Mar 6, 2006
Grant Line Canal near Old River	37º 49' 12.4"	-121º 32' 40.6"	Feb 2, 2007
Victoria Canal	37º 52' 15.5"	-121º 31' 47.9"	Mar 30, 2007

YSI 6600 sondes are approximately 2 feet long and 3.5 inches in diameter. They are completely submersible and self-contained, operating on a minimum of 9 volts of battery power from 8 C-cell alkaline batteries. Deployment data are logged in each sonde's internal memory. Sondes are capable of sampling at many different user-specified frequencies. During 2000, an hourly sampling frequency was used for all stations, approximately 732 samples per month. In 2001, the sampling frequency was changed to a 15-minute interval, approximately 2,920 samples per month. The change to 15-minute intervals allows for a more in-depth review of tidal factors that will influence water quality. For detailed information on YSI instrumentation, visit http://www.ysi.com.

At each monitoring site, a sonde is vertically housed within a 4-inch-diameter PVC pipe in the water column and suspended at a depth of approximately 1 meter. To adjust for changing tides, floats are used to maintain the 1-meter depth. To discourage vandalism the pipes are covered at the top with an end cap and locked with padlocks through two 0.5-inch-diameter bolts. Installation pipes are drilled with 2.25-inch-diameter holes along the length of the pipe and spaced approximately 8 inches to 10 inches on center. Four sets of holes are drilled longitudinally at 90-degree angles from each other. These holes allow ambient water to adequately contact the sonde sensors to ensure accurate data collection. At each site, the sonde installation pipe is either lag-bolted into an existing float structure (wooden boat dock), steel-banded to a pump platform durable enough to withstand long-term usage, or bracketed to a USGS pile.

Each sonde is cleaned and calibrated at Central District's water quality lab to ensure each probe is operating correctly before being deployed. Calibration methods for each constituent are based on YSI's principles of operations. A 3-week rotational period is used year-round as the standard time frame for exchanging out sondes in the south Delta (i.e., a newly calibrated sonde replaces a sonde that had been recording data in ambient conditions for 3 weeks). Field data are collected at each station when a sonde is exchanged during the rotational period for data comparison purposes.

A component of the quality assurance/quality control process involves comprehensive data checking by utilizing separate instrumentation. This instrumentation includes: a YSI-63 handheld unit that measures water temperature, pH, and specific conductance; a Hach Luminescent Dissolved Oxygen handheld unit to check DO concentrations, and a Hach 2100P turbidimeter to measure turbidity. Discrete chlorophyll *a* and pheophytin *a* samples are also collected during each site visit and are processed according to the method described in the "Discrete Monitoring" section, above. A spreadsheet is compiled throughout the year to compare separate field and sonde data for each constituent at every site.

The quality assurance/quality control process continues after each sonde is removed from the field. Each instrument is taken to Central District's water quality lab, where the data are downloaded and the instrument is post-deployed. Post-deployments are performed by checking individual probe readings against calibration standards to determine if errors from probe drift or fouling affected probe accuracy. All readings are taken the day the sonde is removed and before the instrument is cleaned. The data for each constituent are then rated as excellent, good, fair, or poor based on their deviations from the calibration standard according to the USGS technical report *Guidelines and Standard Procedures for Continuous Water-Quality Monitors—Station Operation, Record Computation, and Data Reporting* (Wagner et al. 2006). Data files are then imported into the Central District database Hydstra where quality assurance and quality control checks are performed. The data in Hydstra is used to populate the Water Data Library where the data for all the continuous sites are available online at http://wdl.water.ca.gov/.

Chlorophyll *a* Estimation. The continuous chlorophyll data in combination with regression analysis are used to estimate chlorophyll *a* concentrations in the south Delta. These continuous data are collected by the YSI chlorophyll probe to provide an estimate of total chlorophyll concentrations by measuring fluorescence. Discrete samples for chlorophyll *a* are taken bimonthly at each site for analysis at Bryte Laboratory. The discrete data provide a more accurate representation of ambient chlorophyll *a* concentrations in the south Delta at a specific point in time. Simple linear regression analysis is performed to predict continuous chlorophyll *a* concentrations based on the relationship between the response variable (continuous chlorophyll data) and the independent variable (lab analyzed chlorophyll *a* values). The assumption of normality built into the linear regression model is met by transforming the discrete and continuous chlorophyll data sets into natural logs. Because the regression equation based on the transformed data predicts the geometric mean, which is an estimate of the median, a bias correction method is used to get a more accurate prediction of the mean. This is achieved by using the Maximum Likelihood Estimator method that is valid only for log transformed data. The correction factor is calculated by taking the exponent of 0.5 multiplied by the mean squared error of the regression model.

Data Analysis. The use of summary statistics, such as maximum, mean, minimum, and standard deviation (a measure of variation within a group) are used to compare data for each constituent at all 13 continuous stations. Data for each constituent measured is also presented graphically by waterway (Old River, Middle River, Grant Line Canal, and Victoria Canal).

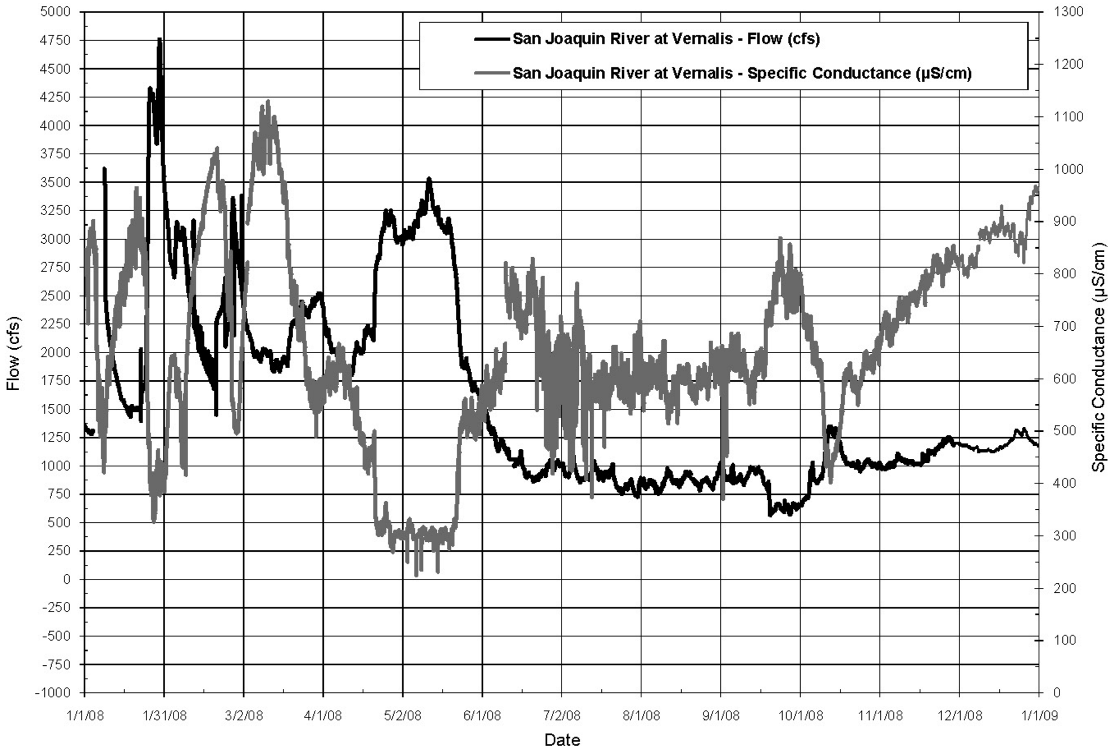
One-way analysis of variance (ANOVA) was used to test for differences among sites in a specific waterway (Old River, Middle River, and Grant Line Canal). An assumption of normality was used based on the number of samples. For every 24-hour period, there are 96 samples recorded at each site, and there are approximately 2,920 samples recorded at each site per month. To look at the data in a more meaningful way, daily averages were calculated for both DO and specific conductance, so the approximate monthly sample size at each site was 30. ANOVA was used to test for mean differences in DO in the months of June, July, and August in Old River, Middle River, and Grant Line Canal. During these months, DO concentrations were the lowest during the year. ANOVA was also used to test for mean differences in specific conductance in each month from April through August in Old River. Then Tukey’s Honestly Significant Difference (HSD) test was performed to determine which pairs of means within a group were significantly different from each other.

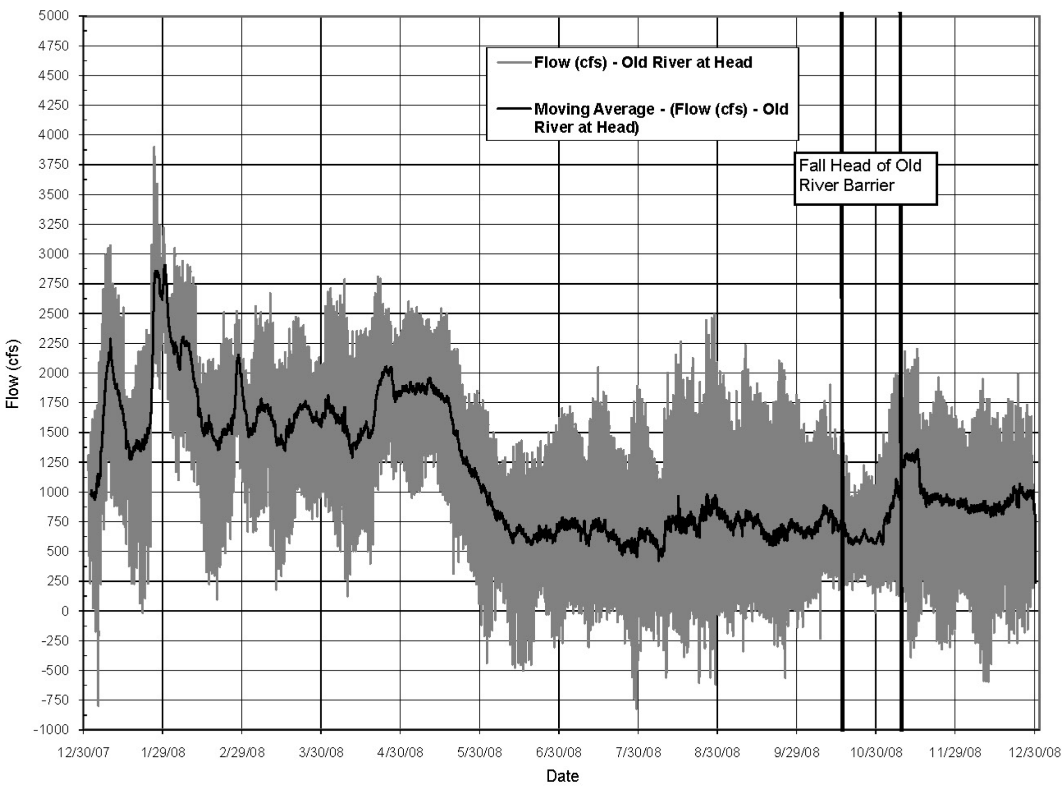
Hydrology

Water year 2008 (October 1, 2007–September 30, 2008) was classified as a critical year for the San Joaquin Valley. Unimpaired runoff was 3.50 million af, and runoff was greatest from April through July. For the Sacramento Valley, water year 2007 was classified as a critical year with unimpaired runoff totaling 10.21 million af.

San Joaquin River flow past Vernalis was highest from March to May and averaged 2,428 cfs. (See Figure 6-3 for flow at San Joaquin River at Vernalis and Old River at head). Average flow during the same time period in 2007 was 2,694 cfs. Flow for 2008 was lowest from July through September and averaged about 854 cfs. Flow at Old River at head ranged from a negative flow (upstream flow) of 814 cfs to a positive flow of 3,900 cfs, with the highest flow observed from January through April.

Figure 6-3. San Joaquin River at Vernalis flow and specific conductance (hourly intervals) and Old River at head flow (15-minute intervals)

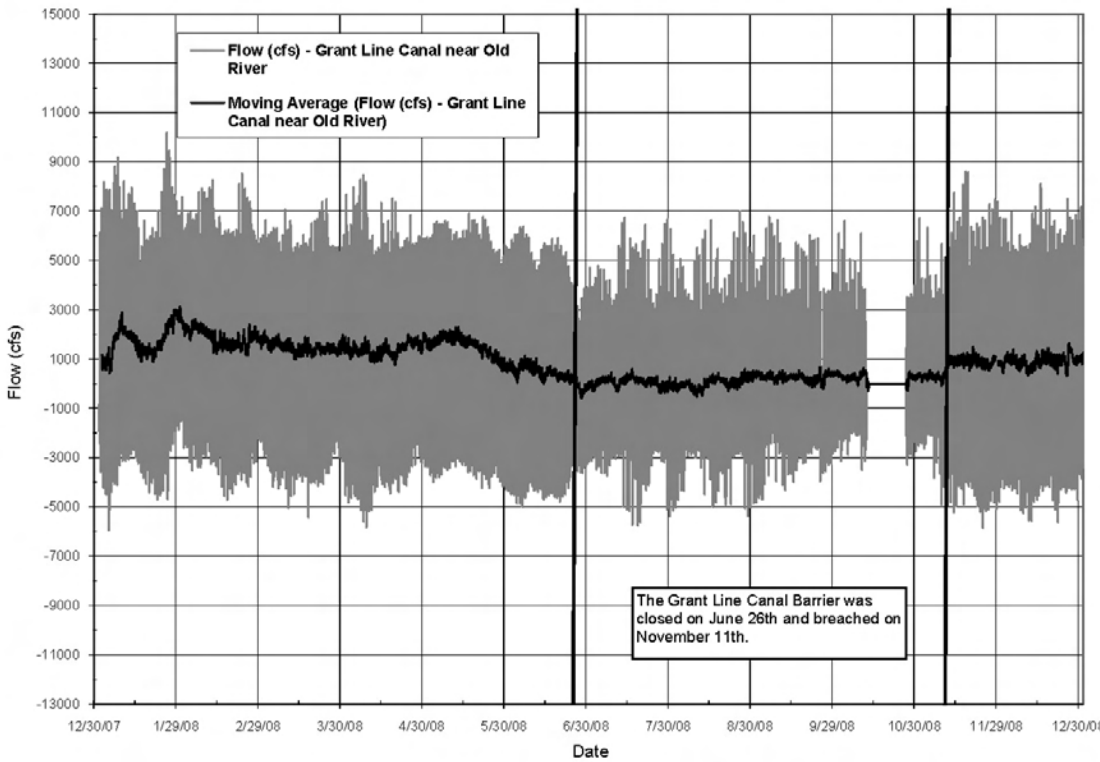




Flow data at Grant Line Canal near Old River were generally more positive (more downstream flow) from January through June and after the GLC barrier was removed in early November (Figure 6-4). Flow ranged from a negative 5,756 cfs to a positive 10,100 cfs during the aforementioned time period. While the GLC barrier was operating, flow ranged from a negative 5,676 cfs to a positive 6,930 cfs, and there was no real distinct flow trend (see the moving average in Figure 6-4). Flow data at Victoria Canal were generally more negative throughout the year (Figure 6-4). Flow values ranged from a negative 9,791 cfs to a positive 5,500 cfs at Victoria Canal in 2008.

Total daily exports for the CVP and SWP averaged 5,200 cfs from January to March. In May and June, exports were the lowest during the year, averaging 1,654 cfs and 1,651 cfs, respectively. (See Figure 6-5 for SWP and CVP total daily exports [cfs]). From July through December, daily exports averaged 4,620 cfs. (Note: All CVP and SWP pumping data are preliminary and have not been checked for accuracy.)

Figure 6-4. Grant Line Canal near Old River flow (15-minute intervals) and Victoria Canal flow (15-minute intervals)



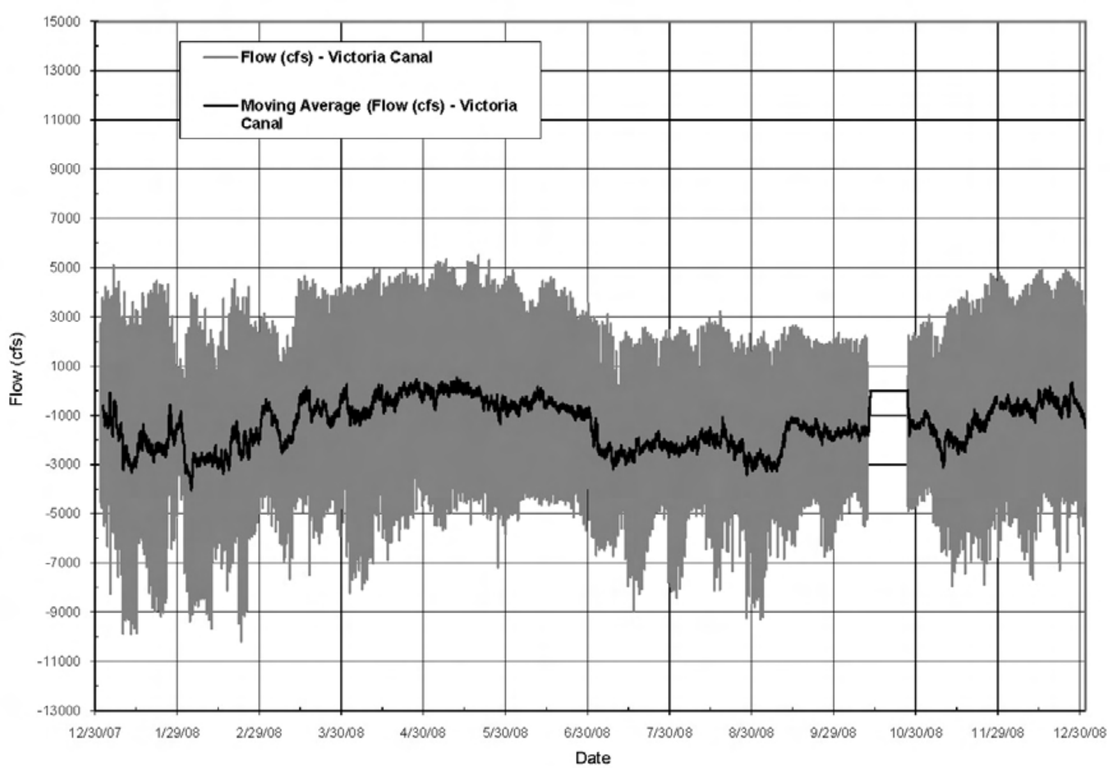
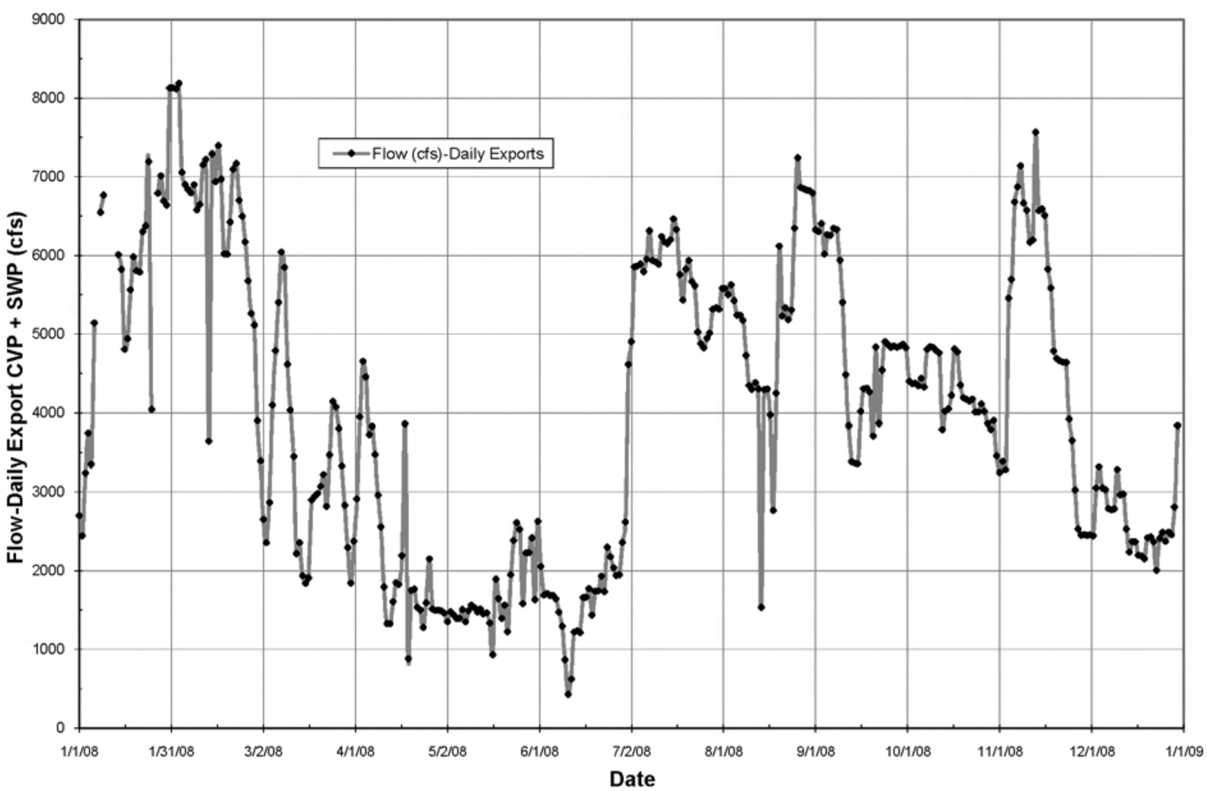


Figure 6-5. Daily combined State Water Project and Central Valley Project exports



Results

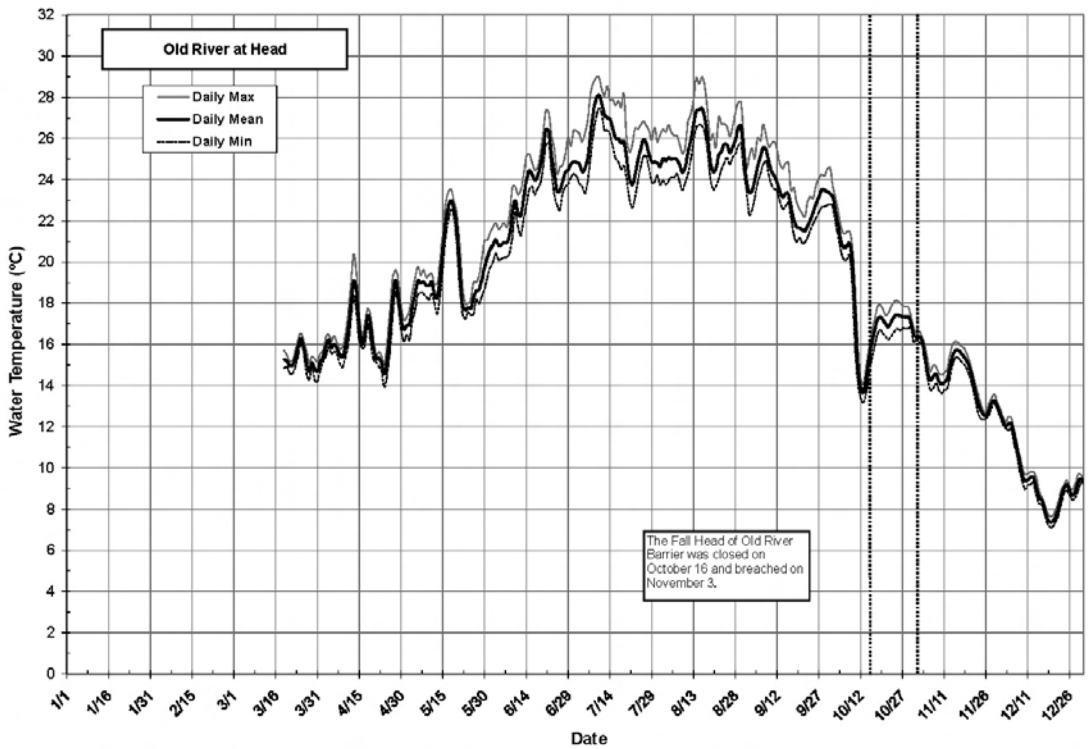
Water Temperature

Temperature affects pH, conductance, the solubility of constituents such as DO, the rate of chemical reactions, and biological activity in water (Radtke et al. 2004). It is also probably the single most important factor affecting fish distribution both between and within estuaries seasonally, though temperature effects are closely tied to the effects of other variables (Moyle and Cech Jr. 2000).

A maximum water temperature of 30.21 °C (86.4 ºF) was recorded on July 8 at Middle River near Tracy Boulevard, and a minimum of 5.39 °C (41.7 ºF) was recorded on January 2 at Middle River at Howard Road. (Figures 6-6 to 6-12.) Tables 6-3 to 6-5 provide a statistical summary of the 2008 water quality data collected in the south Delta. Temperature patterns followed seasonal trends, with the highest temperatures occurring in summer, and the lowest occurring in winter. Monthly mean temperatures in the summer ranged from 22.26 ºC (72.1 ºF) in June at Old River downstream of the ORT barrier to 25.88 ºC (78.6 ºF) at Middle River at Howard Road in August. In the winter, monthly mean temperatures ranged from 8.03 ºC (46.5 ºF) in January at Middle River near Tracy Boulevard to 13.31 ºC (56.0 ºF) in February at Victoria Canal. Water temperatures in spring and fall exhibited the steepest increases and decreases in temperature in accordance with seasonal temperature changes. Mean temperatures for the monitoring period at stations with a full data set ranged from 17.11 °C (62.8 ºF) at Old River upstream of the ORT barrier to 17.83 °C (64.1 ºF) at Doughty Cut above Grant Line Canal.

In 2007, water temperatures ranged from a minimum of 2.48 °C (36.5 ºF) in January to a maximum of 31.02 °C (87.8 ºF) in July. Mean temperatures for the monitoring period ranged from 17.09 °C (62.8 ºF) to 17.67 °C (63.8 ºF).

Figure 6-6. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) water temperature data



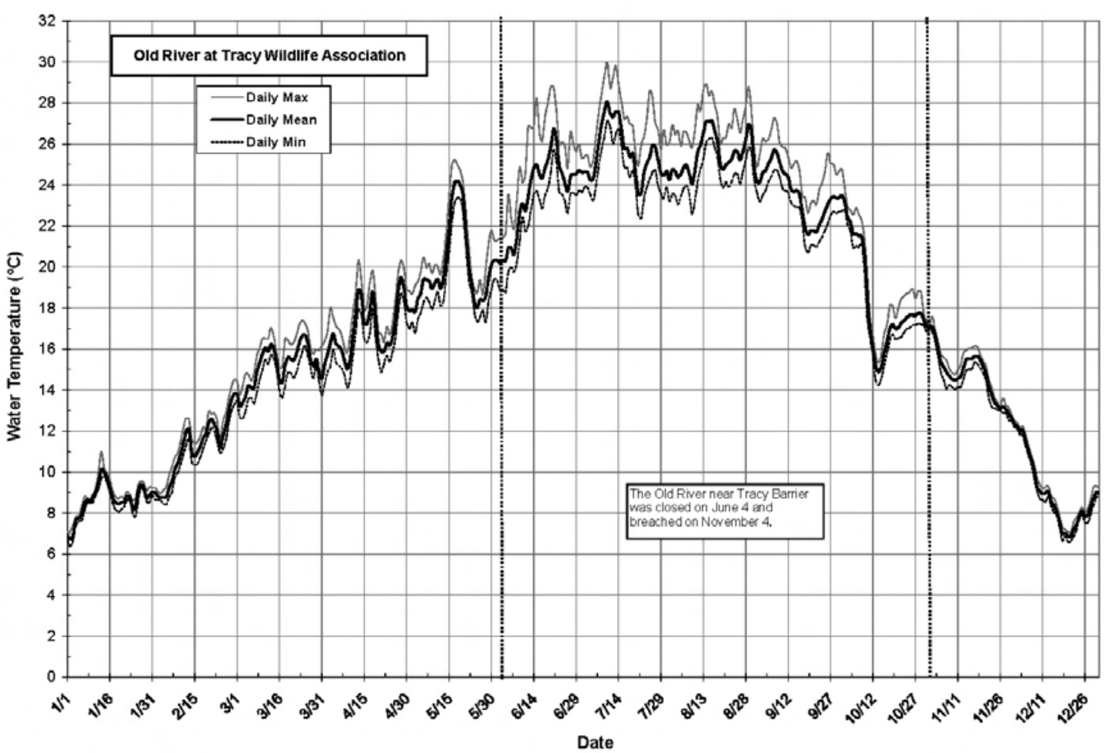


Figure 6-7. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) water temperature data

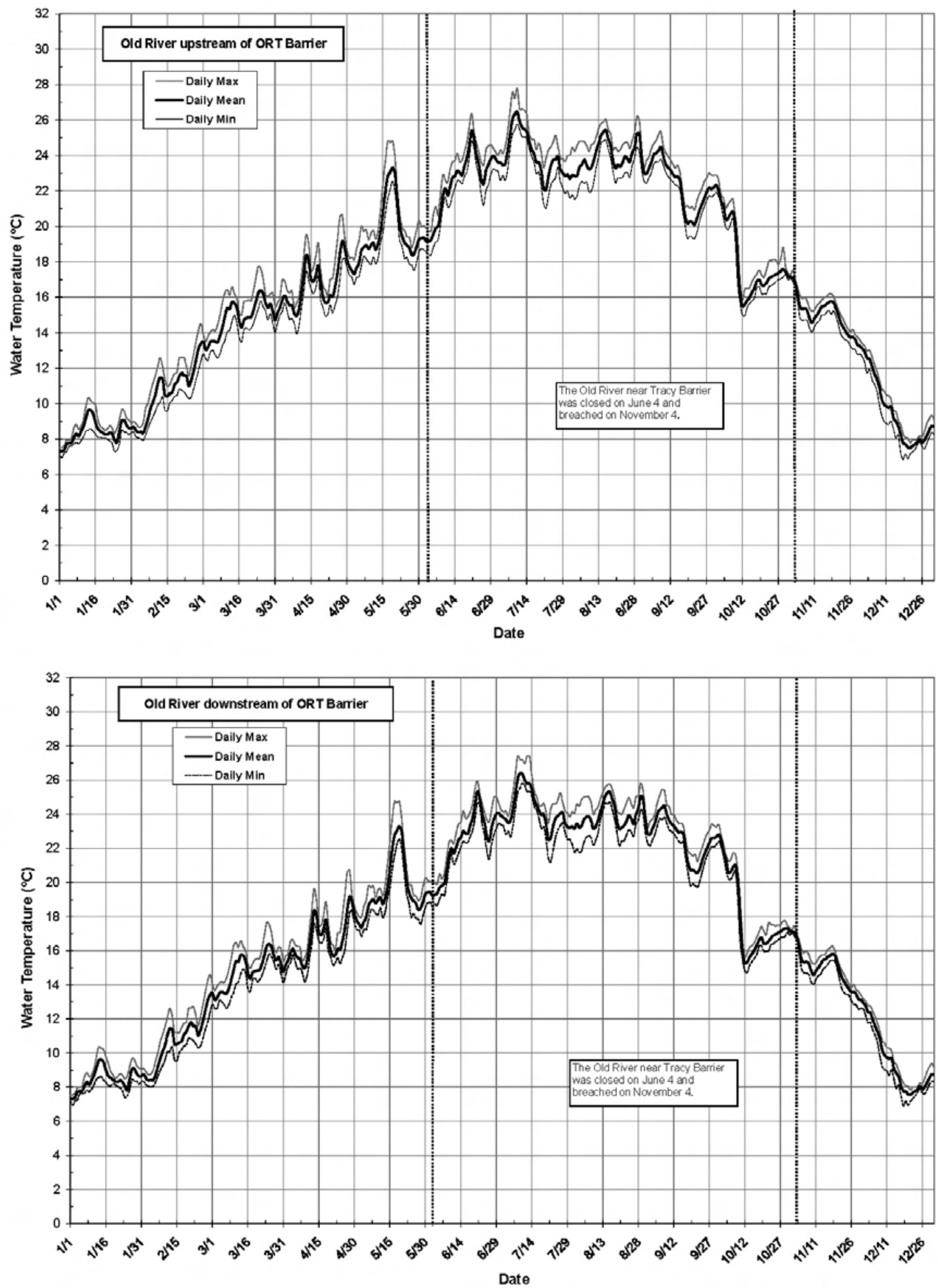
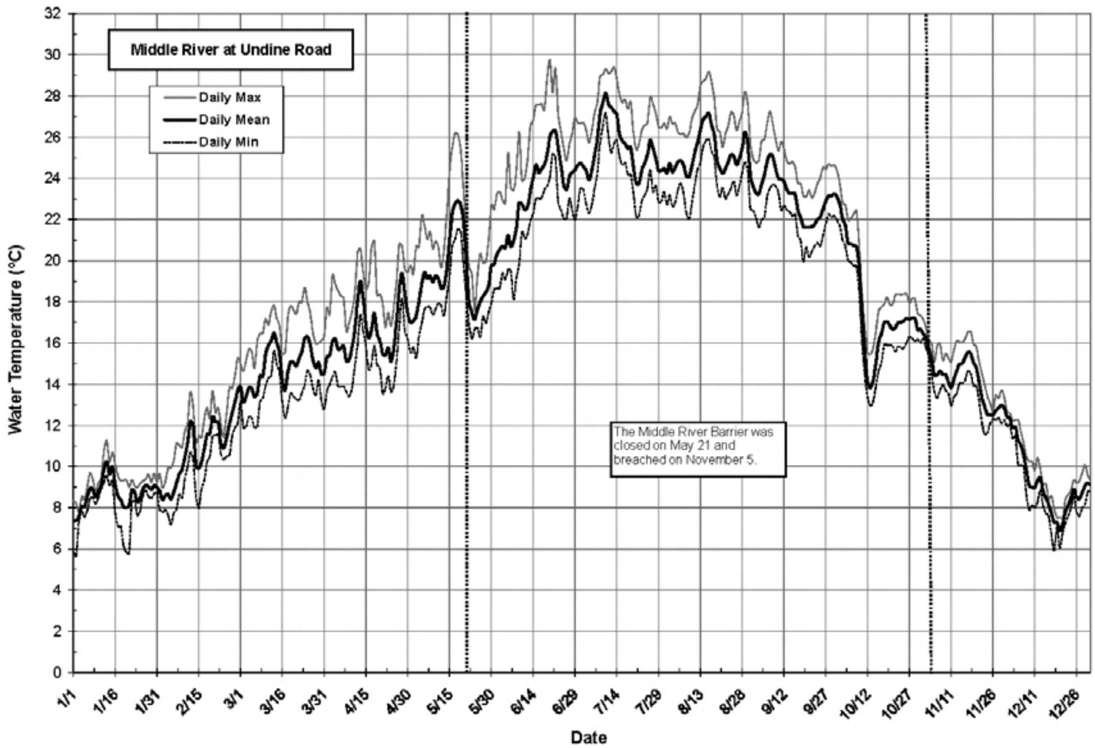


Figure 6-8. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) water temperature data



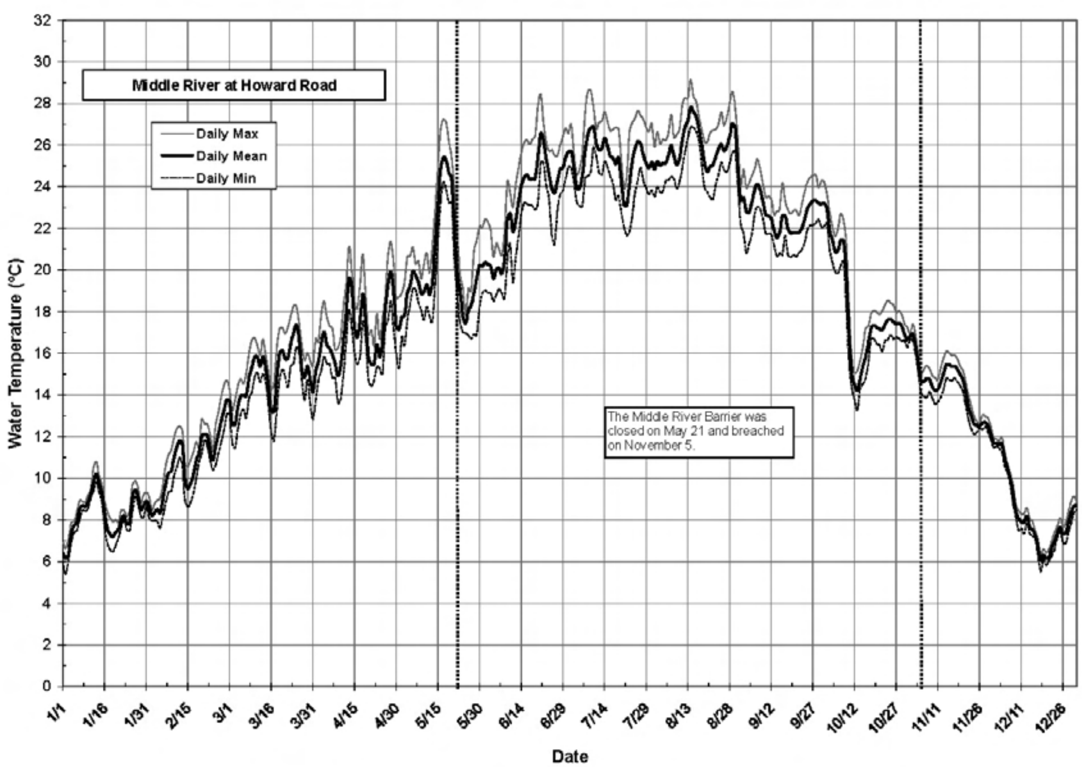
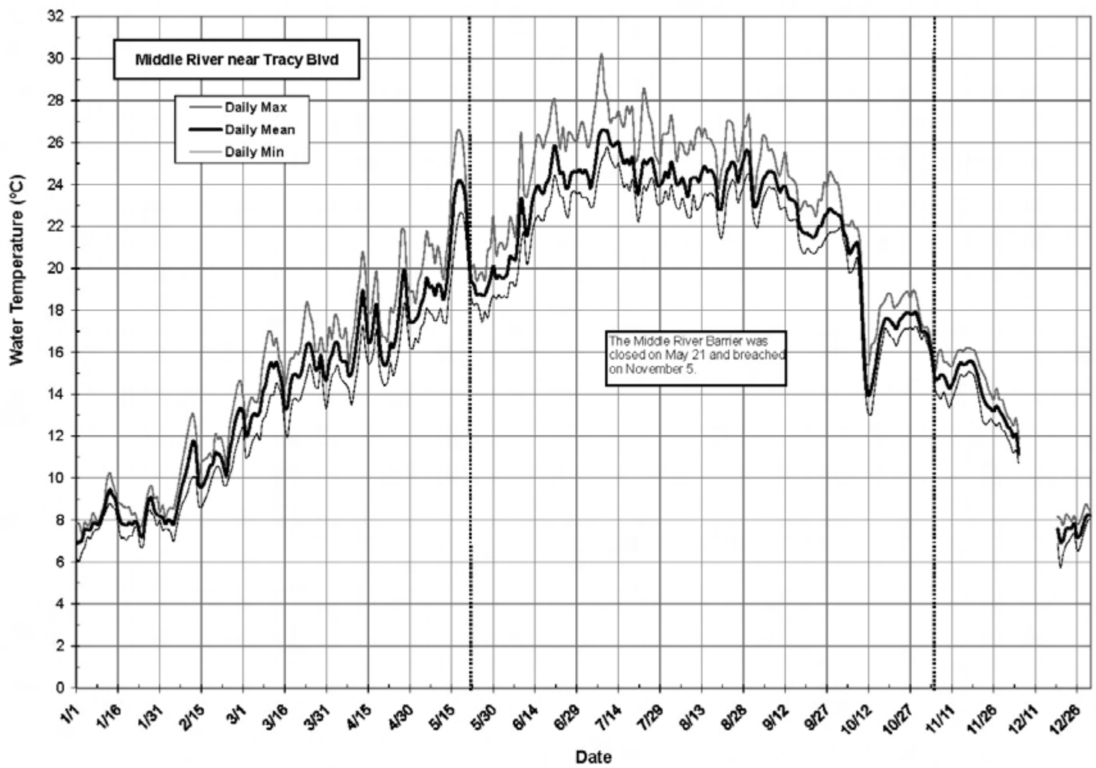


Figure 6-9. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) water temperature data



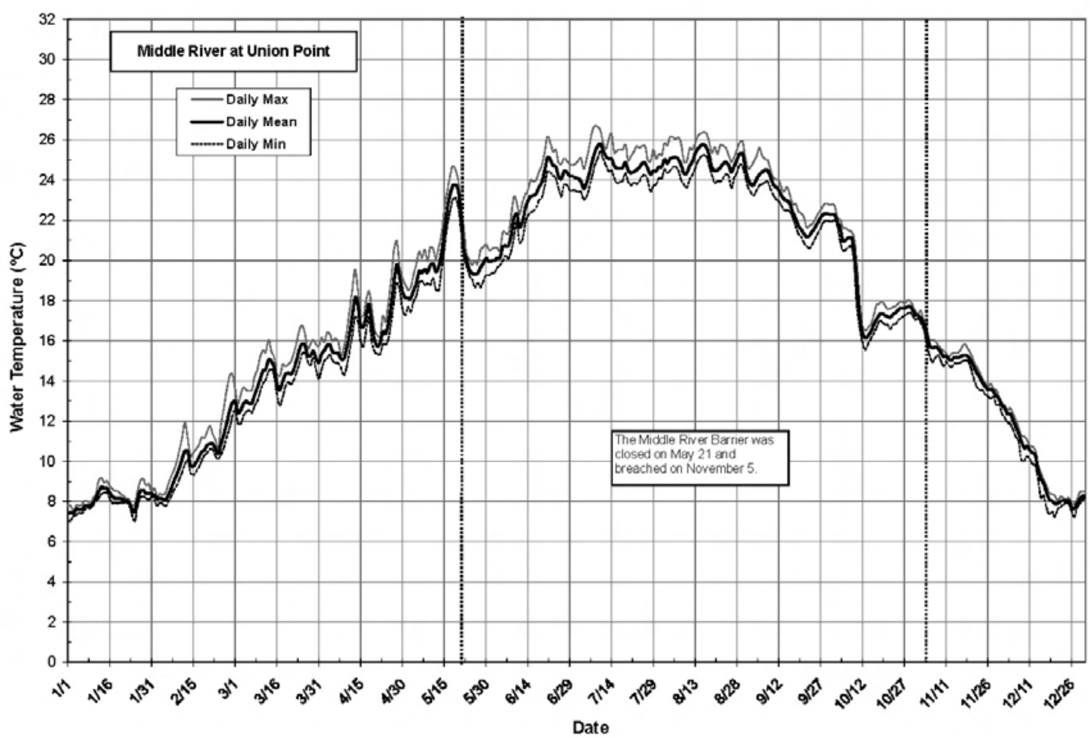
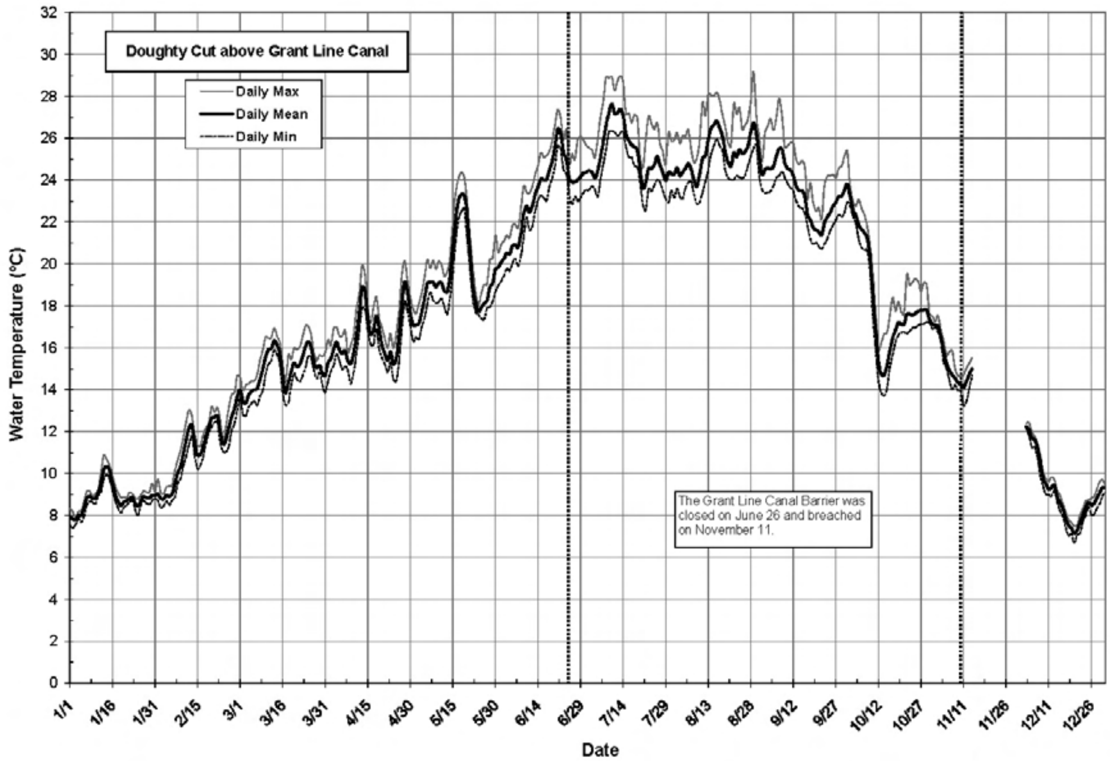


Figure 6-10. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) water temperature data



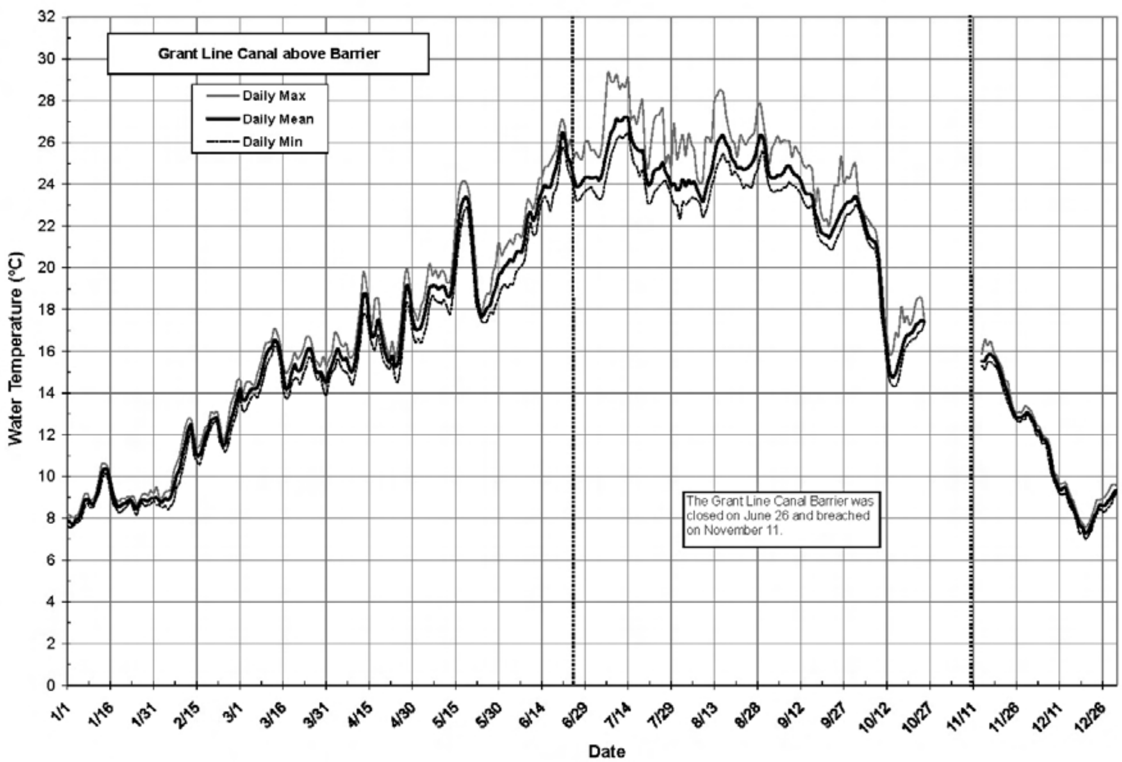
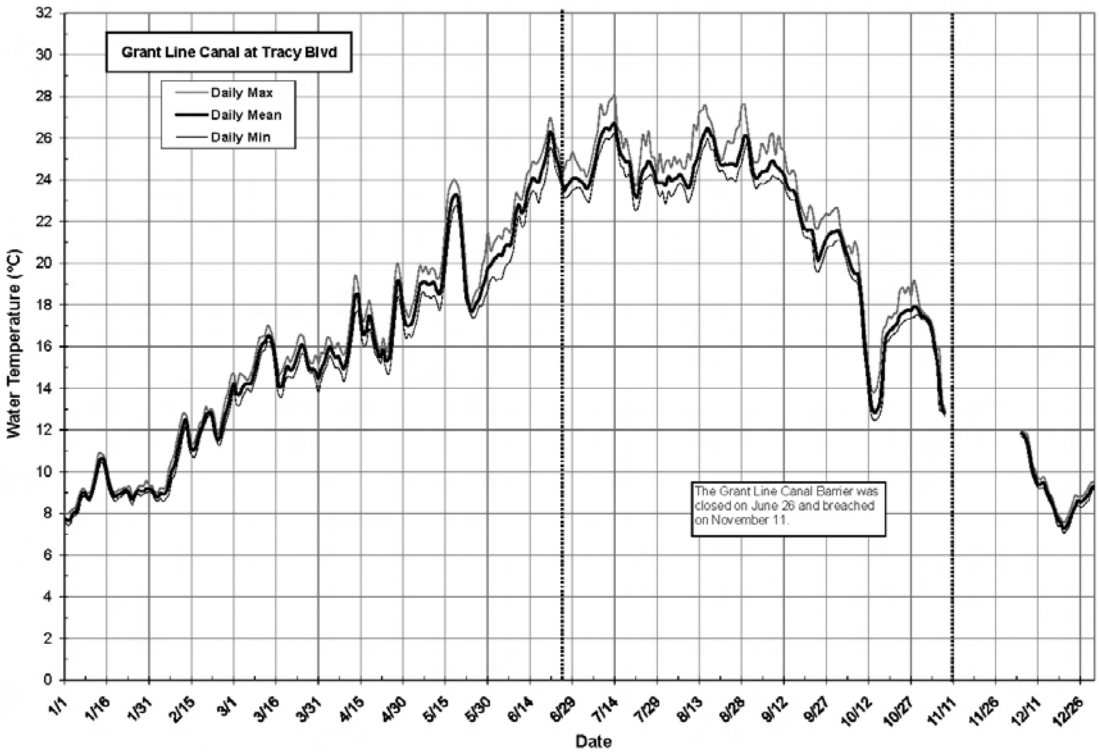


Figure 6-11. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) water temperature data



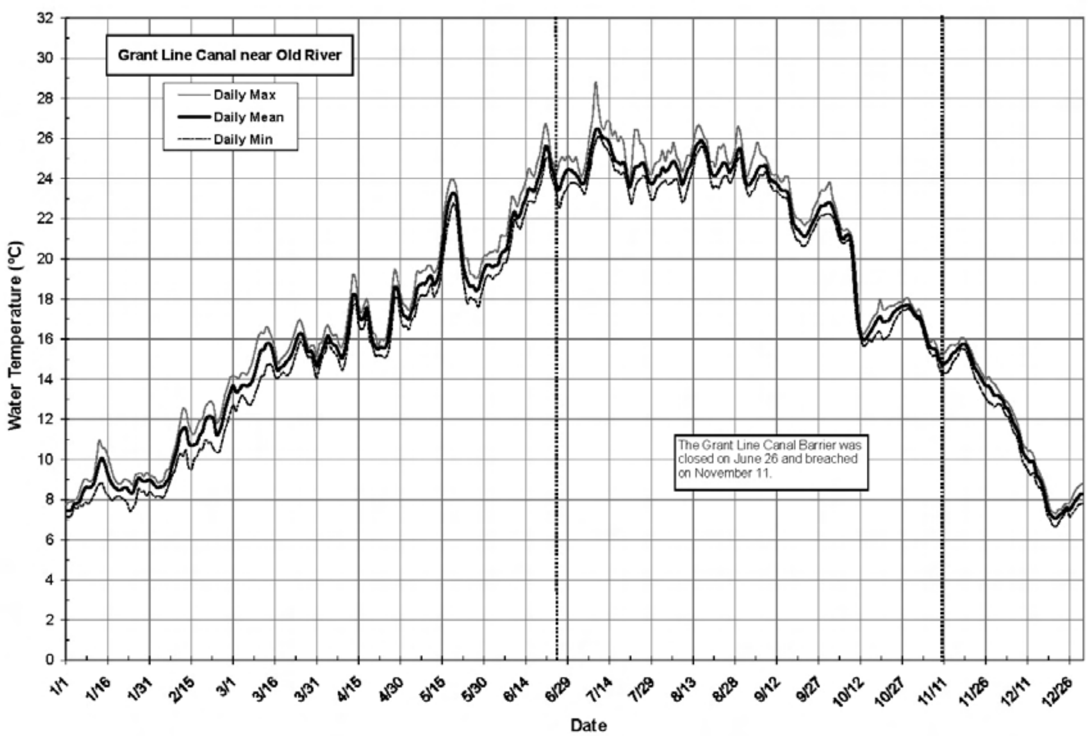
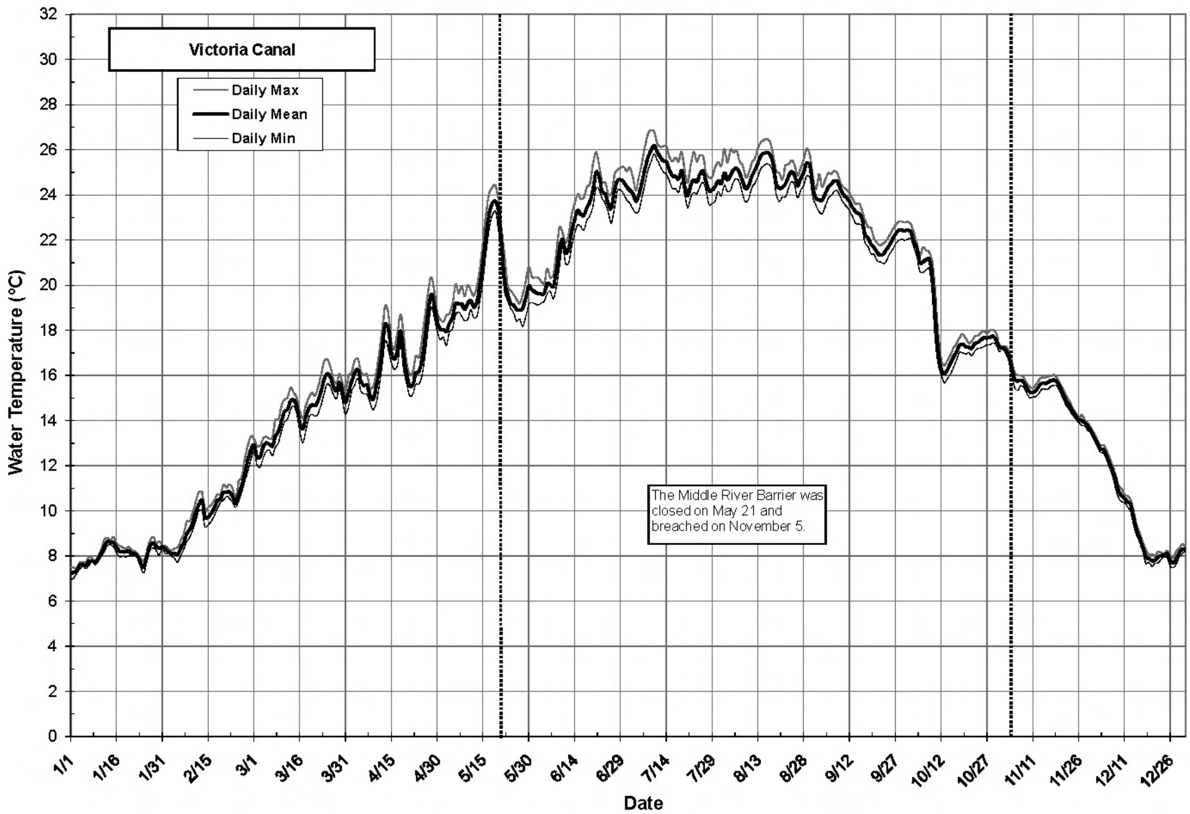


Figure 6-12. Victoria Canal daily (maximum, mean, minimum) water temperature data

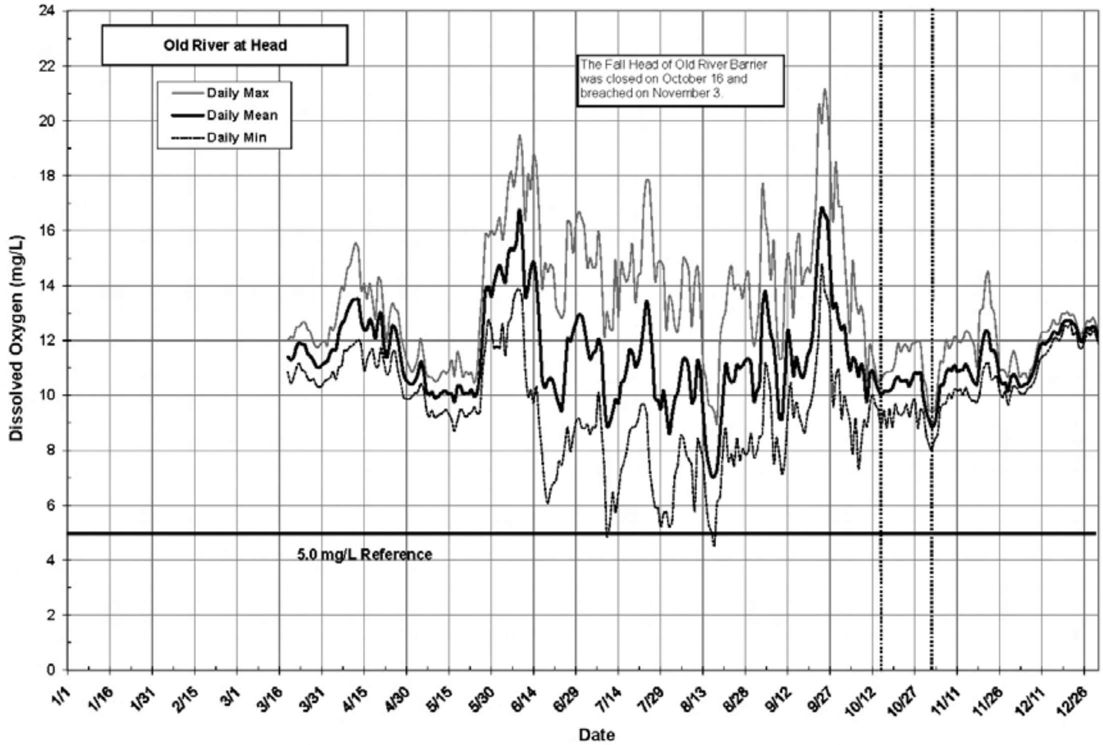


Dissolved Oxygen

One of the most important measures of water quality is the amount of DO (Masters 1997). The EPA has established national ambient water quality criteria for inorganic constituents, such as DO, to protect freshwater aquatic life. However, there is considerable variability in DO tolerances among fish and other aquatic life. For a warm water system like the Delta, minimum DO criteria for early aquatic life stages (embryos, larvae, and juveniles less than 30 days old) was set at 5 mg/L. For other life stages (older juveniles and adults) it was set at 3 mg/L (Marshack 2000). Sources of DO in surface waters are primarily atmospheric reaeration and photosynthetic activity of aquatic plants (Lewis 2005). DO saturation is inversely related to water temperature (i.e., as water temperature increases, DO saturation decreases). Supersaturated DO conditions can occur as a result of excess photosynthetic production of oxygen by phytoplankton or aquatic plants. The depletion of DO can occur by inorganic oxidation reactions or by biological or chemical processes that consume dissolved, suspended, or precipitated organic matter (Hem 1989).

Winter (January, February, and December 2008). A maximum DO concentration of 14.61 mg/L was measured on December 20 at Old River at the Tracy Wildlife Association, and a minimum of 6.47 mg/L was recorded on January 13 at Old River upstream of the ORT barrier (Figures 6-13 to 6-19 and Tables 6-3 to 6-6.) Monthly mean DO concentrations during this time period ranged from 9.37 mg/L in February at Old River downstream of the ORT barrier to 11.94 mg/L in December at Middle River near Tracy Boulevard. The expected range of DO values in the winter (assuming 100% saturation) based on water temperature, salinity, and local barometric pressure was between 9.97 mg/L and 12.56 mg/L. Actual DO saturation values ranged from 57% to 125% (6.47–14.61 mg/L).

Figure 6-13. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) dissolved oxygen data



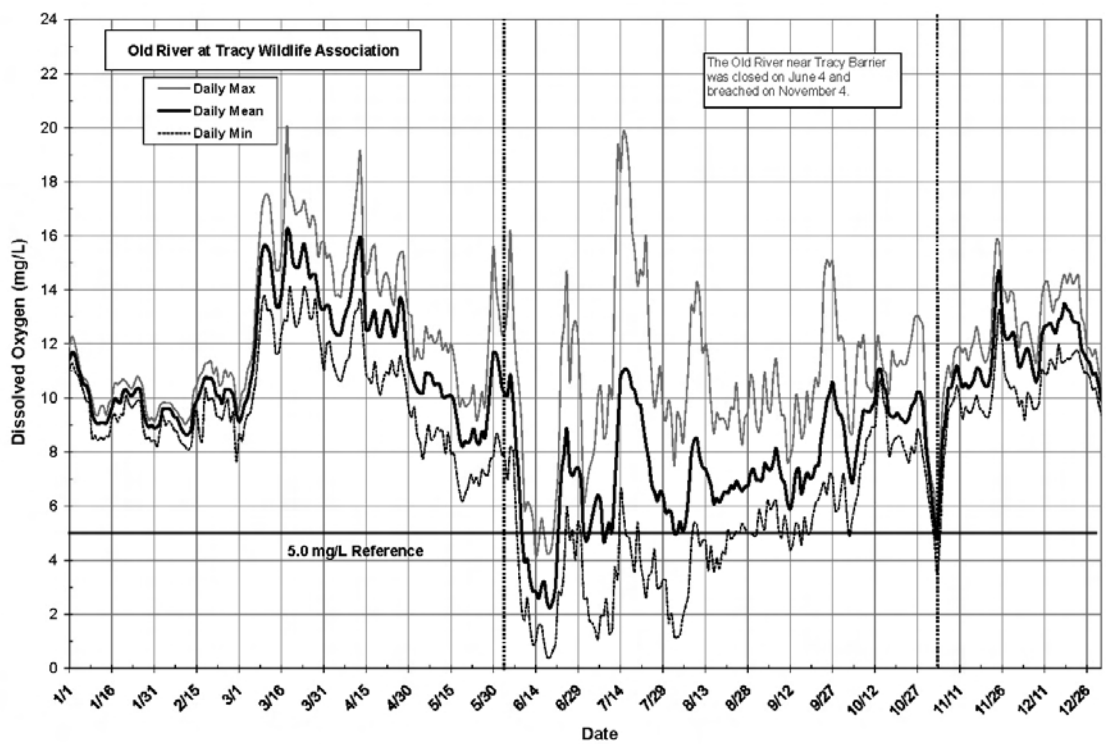
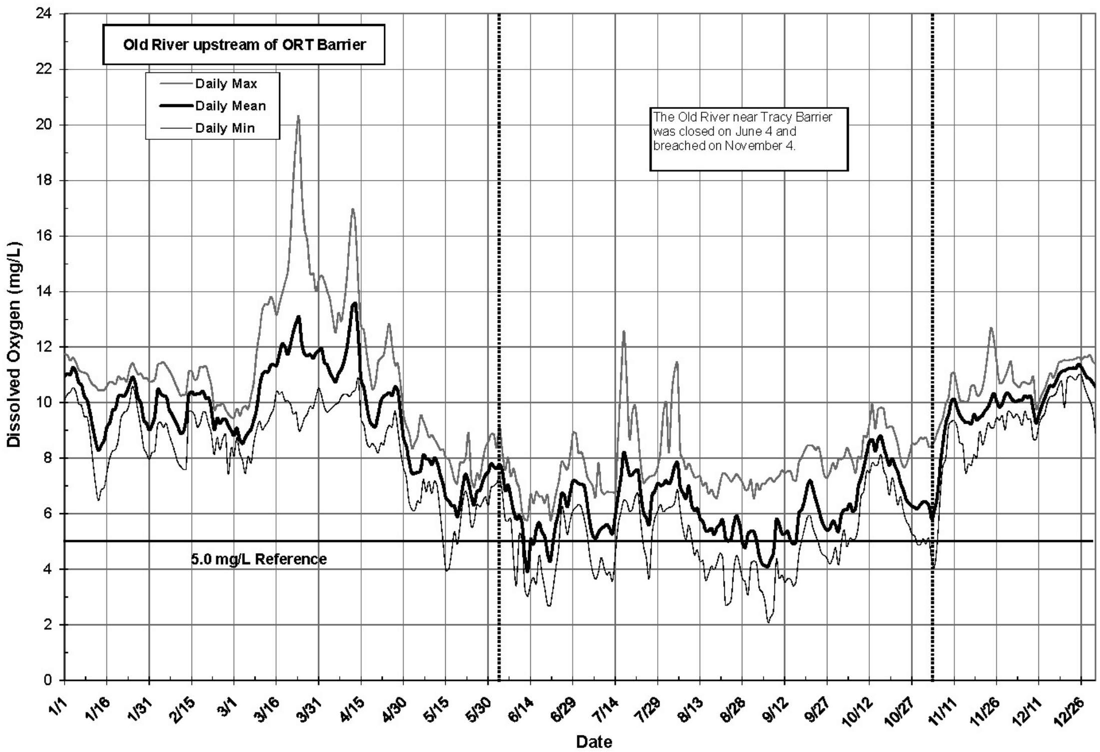


Figure 6-14. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) dissolved oxygen data



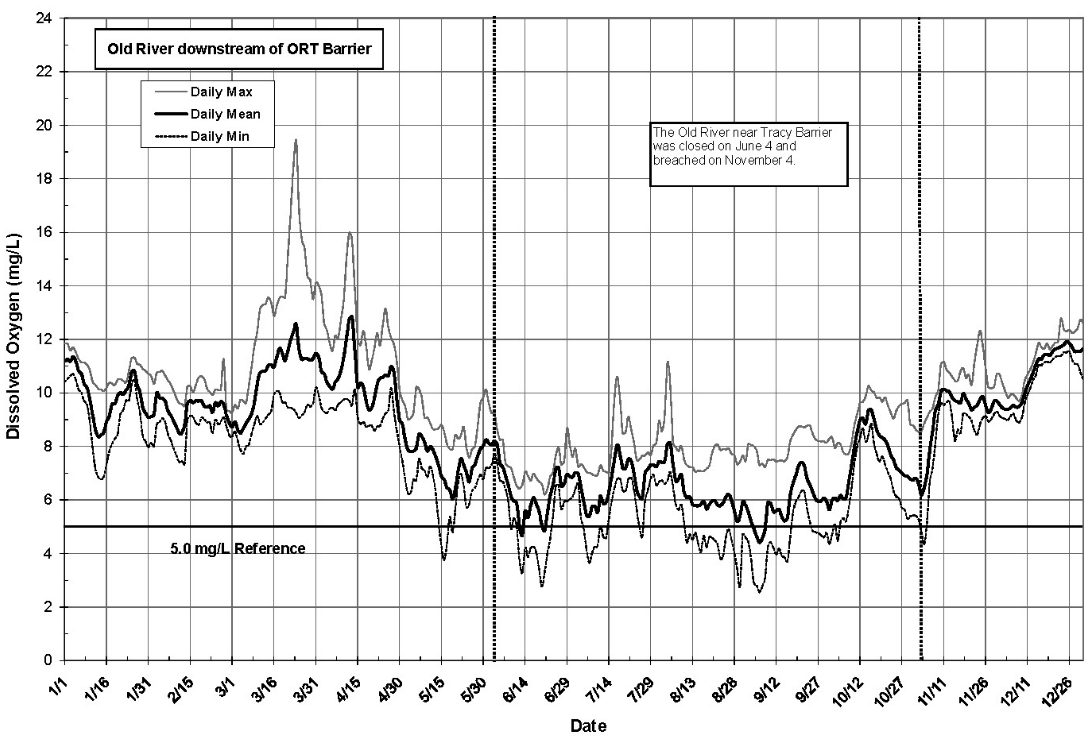
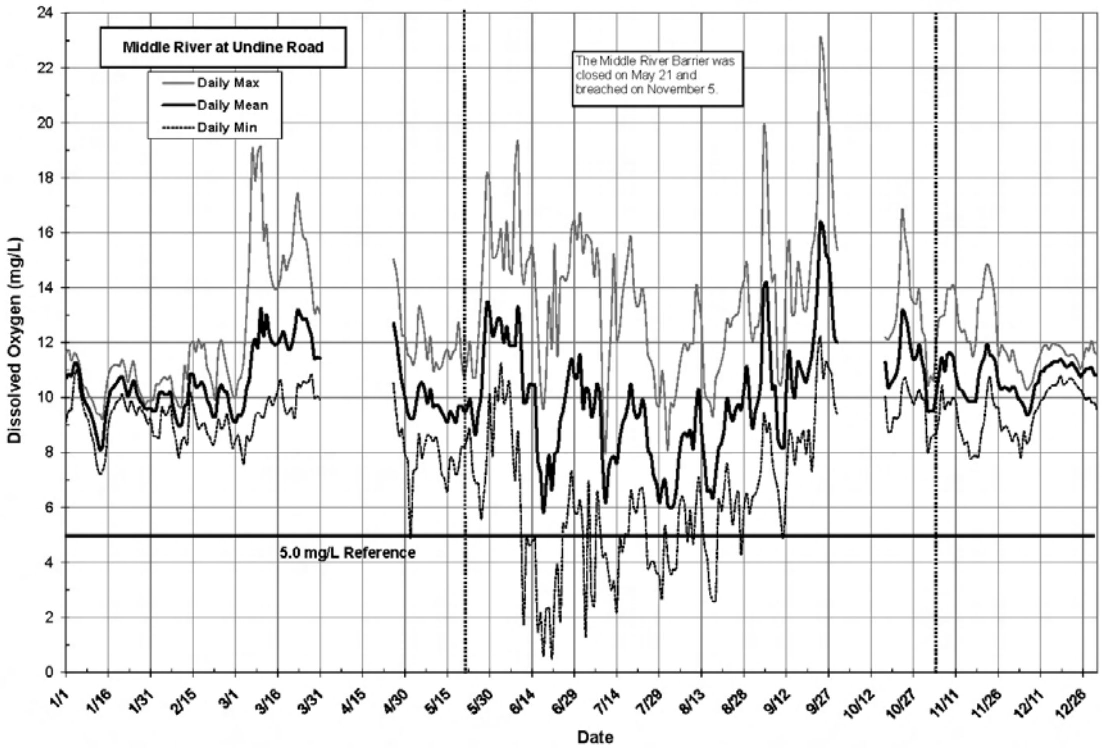


Figure 6-15. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) dissolved oxygen data



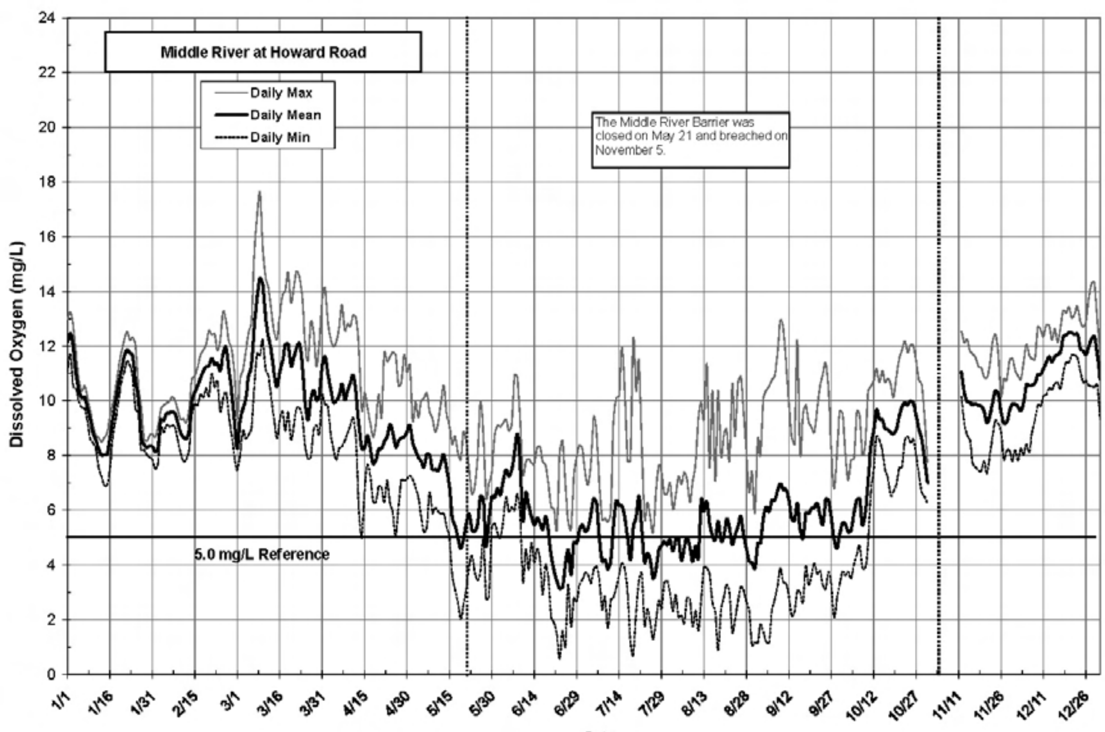
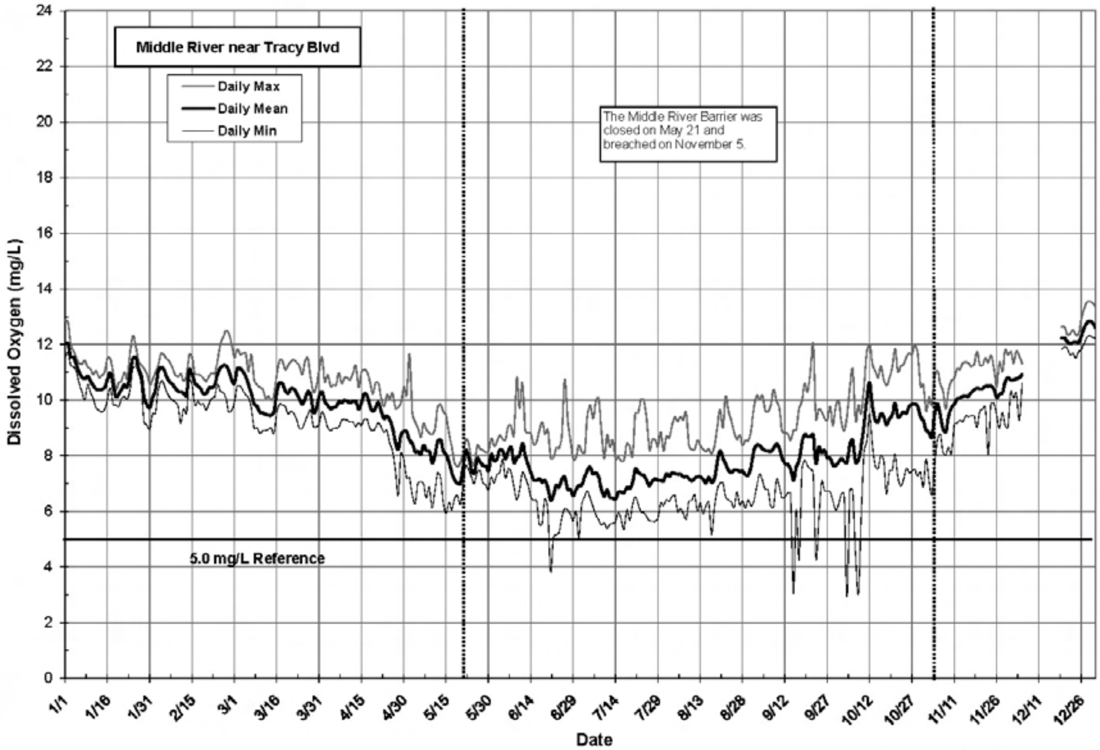


Figure 6-16. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) dissolved oxygen data



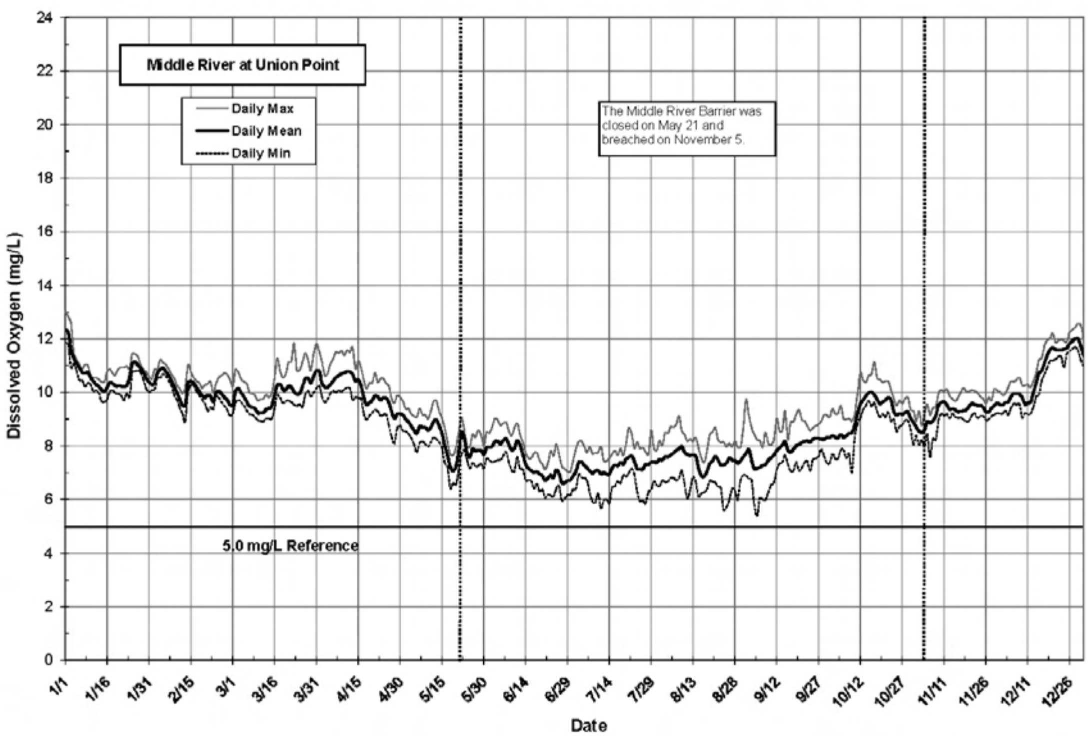
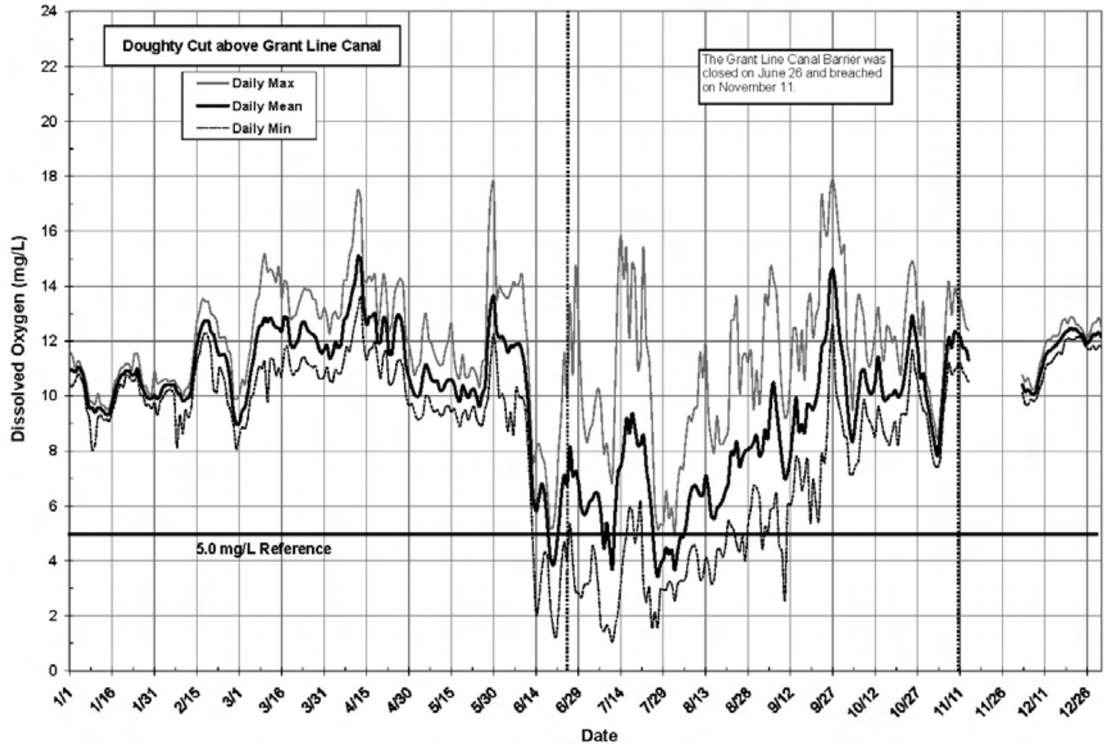


Figure 6-17. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) dissolved oxygen data



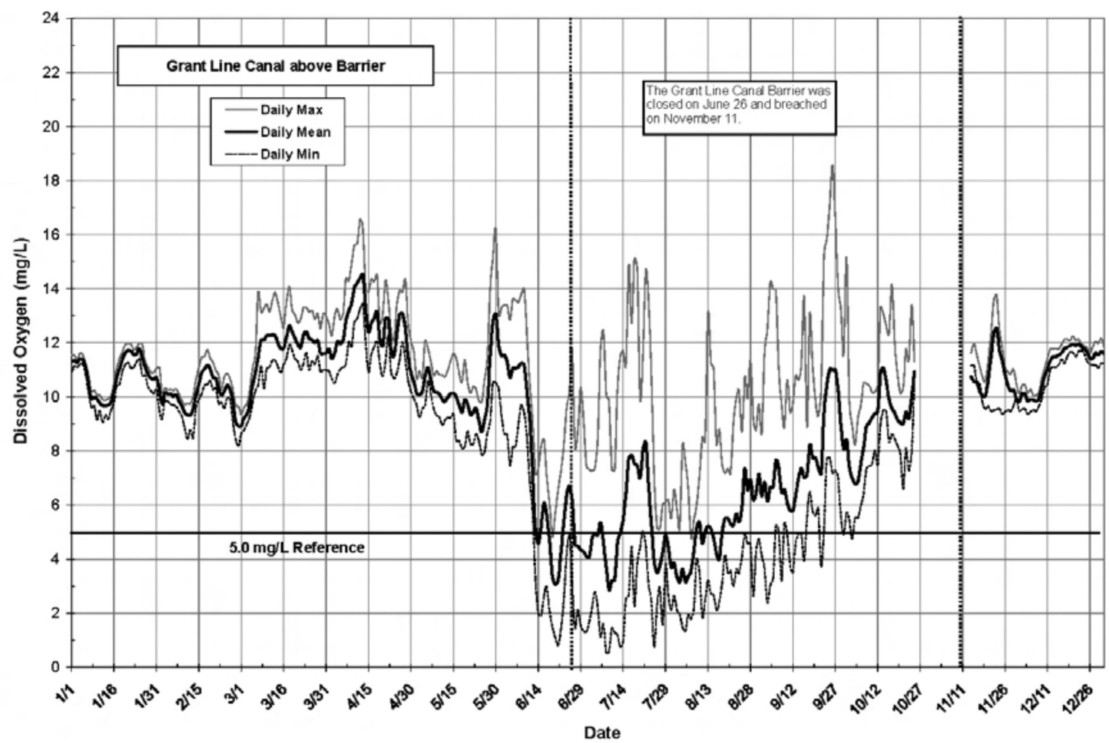
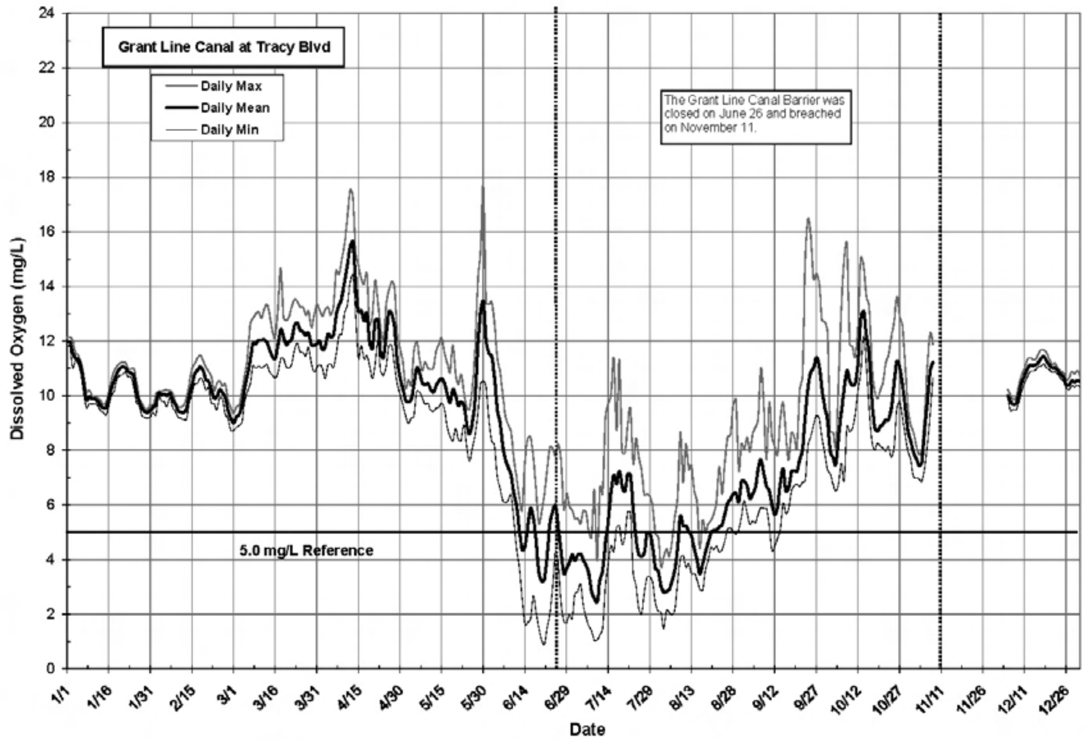


Figure 6-18. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) dissolved oxygen data



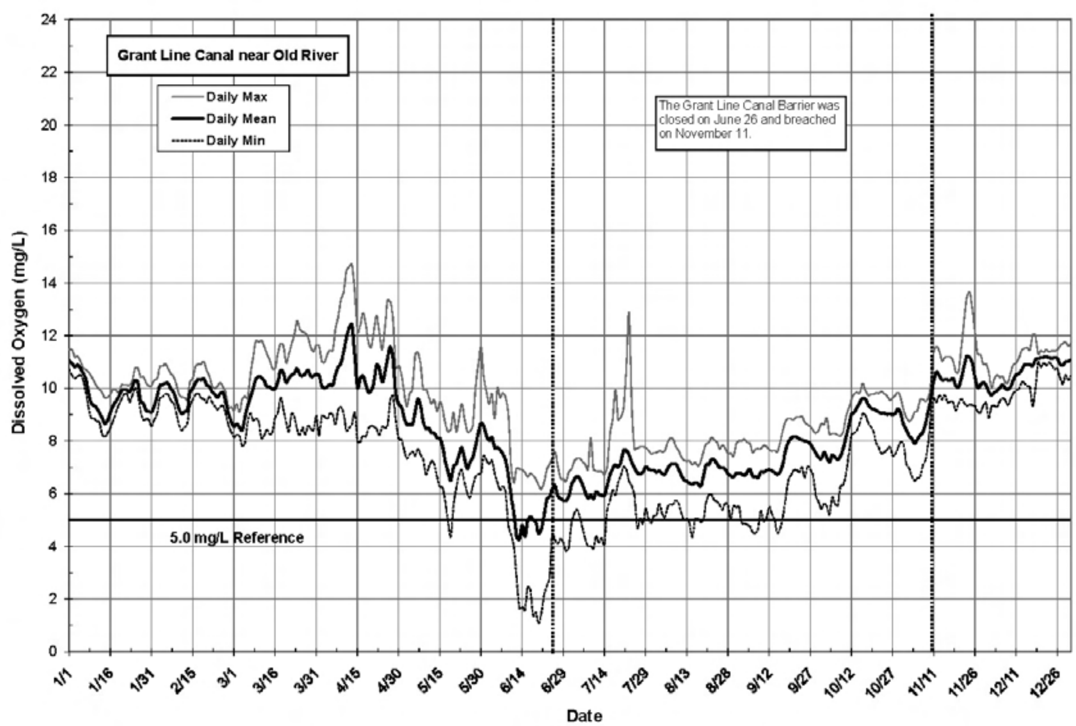


Figure 6-19. Victoria Canal daily (maximum, mean, minimum) dissolved oxygen data

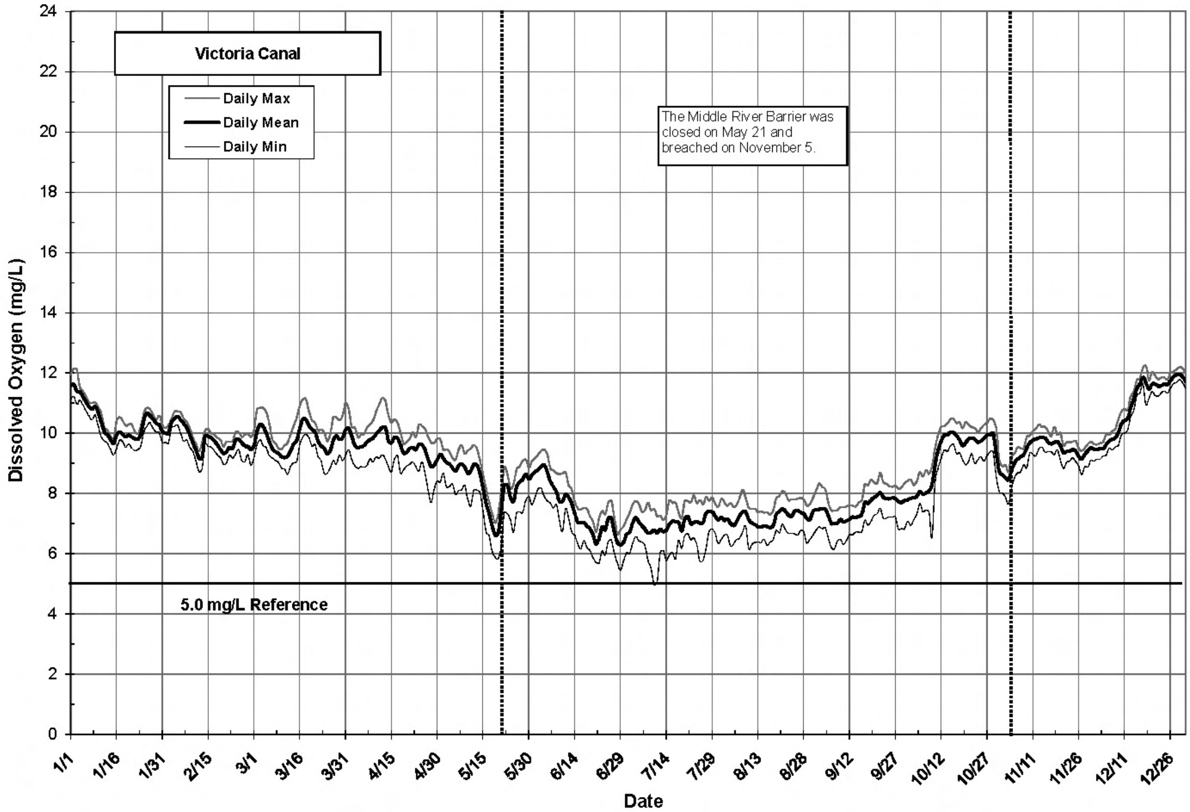


Table 6-3. Statistical summary of 2008 Old River continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Maximums	**Near head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	10.99	10.33	10.35
February	-	14.49	14.51	14.58
March	16.55	17.38	17.75	17.66
April	20.38	20.32	20.65	20.70
May	23.51	25.24	24.84	24.74
June	27.35	28.76	26.36	25.96
July	28.98	29.96	27.80	27.41
August	28.98	28.92	26.23	25.82
September	26.68	27.36	25.34	25.44
October	24.58	24.77	22.89	23.38
November	16.62	17.57	17.53	17.46
December	12.83	12.51	13.35	13.17
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	8.60	8.40	8.42
February	-	11.09	10.63	10.64
March	15.23	15.16	14.80	14.82
April	16.46	16.95	16.61	16.63
May	19.17	19.94	19.54	19.52
June	23.27	23.47	22.29	22.26
July	25.67	25.57	24.06	24.26
August	25.56	25.47	23.92	23.92
September	23.33	23.59	22.33	22.57
October	17.95	18.39	18.04	17.94
November	14.45	14.78	15.05	14.99
December	9.52	8.98	9.47	9.41

Month	Dissolved oxygen (mg/L)			
Maximums	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	12.28	11.75	11.84
February	-	11.38	11.46	11.26
March	12.65	20.07	20.23	19.41
April	15.54	19.04	16.96	15.99
May	16.00	15.58	9.53	10.21
June	19.46	16.19	9.11	9.57
July	17.87	19.85	12.57	10.61
August	15.00	14.30	11.43	11.14
September	21.13	15.09	8.46	8.78
October	16.87	13.05	9.93	10.26
November	14.48	15.89	12.68	12.33
December	13.03	14.61	11.71	12.77
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	9.94	9.96	9.94
February	-	9.73	9.72	9.37
March	11.47	13.70	10.95	10.62
April	12.23	13.15	10.81	10.61
May	10.79	9.80	7.22	7.51
June	12.99	6.14	6.02	6.39
July	10.98	7.35	6.48	6.65
August	9.95	6.64	5.99	6.29
September	12.42	7.77	5.48	5.85
October	10.68	9.23	7.13	7.50
November	10.73	10.51	9.05	9.07
December	11.81	11.92	10.55	10.79

Month	pH			
Maximums	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	8.12	7.90	8.14
February	-	8.13	7.97	7.95
March	8.60	8.96	9.07	9.11
April	8.95	9.06	8.99	9.07
May	9.13	8.92	8.17	8.30
June	9.42	9.18	8.59	8.65
July	9.66	8.95	8.75	8.51
August	9.12	8.66	8.55	8.49
September	9.34	8.81	7.87	8.20
October	8.90	8.50	8.44	8.24
November	8.69	8.91	8.13	8.55
December	8.29	8.62	8.44	8.62
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	7.75	7.52	7.79
February	-	7.82	7.58	7.47
March	8.34	8.36	8.03	8.01
April	8.27	8.60	8.18	8.23
May	7.95	7.97	7.54	7.43
June	9.07	7.74	7.62	7.64
July	9.00	7.01	7.54	7.53
August	8.63	7.81	7.56	7.50
September	8.57	7.91	7.56	7.68
October	7.76	7.97	7.71	7.77
November	7.92	8.02	7.60	7.97
December	8.06	8.23	7.83	8.08

Table 6-3 (cont.). Statistical summary of 2008 Old River continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Minimums	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	6.37	6.93	6.93
February	-	8.40	7.93	8.01
March	14.20	12.61	12.45	12.59
April	13.92	14.10	13.94	14.18
May	16.14	16.79	16.73	16.82
June	19.74	18.76	18.38	18.62
July	22.63	22.37	21.03	21.18
August	23.48	22.60	21.53	21.78
September	20.92	20.70	19.31	19.72
October	13.17	19.25	14.96	14.71
November	12.37	12.49	12.75	12.57
December	7.11	6.60	6.83	6.91
Std. devs.	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	0.83	0.68	0.68
February	-	1.48	1.47	1.47
March	0.53	1.05	1.06	1.05
April	1.29	1.38	1.31	1.30
May	1.72	2.04	1.77	1.73
June	1.79	2.10	1.87	1.84
July	1.33	1.45	1.28	1.18
August	1.07	1.21	0.96	0.85
September	1.23	1.36	1.43	1.23
October	2.67	2.52	2.06	2.28
November	1.16	1.22	1.05	1.10
December	1.53	1.67	1.82	1.75
2008—Max.	28.98	29.96	27.80	27.41
2008—Avg.	19.29	17.68	17.11	17.13
2008—Min.	7.11	6.37	6.83	6.91
2008—S.D.	5.37	6.09	5.54	5.57

Month	Dissolved oxygen (mg/L)			
Minimums	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	8.40	6.47	6.77
February	-	7.65	7.42	7.33
March	10.30	8.41	7.46	7.72
April	9.87	9.66	7.65	7.99
May	8.70	6.17	3.97	3.76
June	6.07	0.40	2.70	2.76
July	4.90	1.09	3.58	3.65
August	4.56	1.15	2.71	2.77
September	7.13	4.39	2.10	2.55
October	7.35	4.90	4.15	4.36
November	8.00	3.55	4.08	4.34
December	10.06	9.18	8.69	8.88
Std. devs.	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	0.83	1.13	1.13
February	-	0.71	0.83	0.69
March	0.58	2.27	2.01	1.86
April	1.07	1.48	1.55	1.29
May	1.44	1.45	0.86	0.94
June	2.78	3.25	1.23	1.14
July	2.44	3.22	1.17	1.00
August	2.12	1.97	1.23	1.22
September	2.53	1.76	1.31	1.41
October	1.00	1.34	1.20	1.39
November	1.02	2.35	1.50	1.36
December	0.83	1.16	0.64	0.98
2008—Max.	21.13	20.07	20.23	19.41
2008—Avg.	11.39	9.66	8.27	8.38
2008—Min.	4.56	0.40	2.10	2.55
2008—S.D.	2.02	3.86	2.37	2.19

Month	pH			
Minimums	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	7.47	7.20	7.51
February	-	7.55	7.28	7.18
March	8.12	7.75	7.62	7.61
April	7.57	8.05	7.73	7.74
May	7.42	7.48	7.23	7.03
June	8.65	7.28	7.24	7.32
July	8.50	7.64	7.19	7.25
August	8.03	6.75	7.27	7.28
September	8.00	7.40	7.34	7.36
October	7.14	7.62	7.34	7.48
November	7.57	7.34	7.36	7.67
December	7.82	7.66	7.41	7.65
Std. devs.	**Near Head**	**Tracy Wildlife Association**	**Above ORT bar.**	**Below ORT bar.**
January	-	0.17	0.18	0.17
February	-	0.15	0.17	0.15
March	0.12	0.28	0.40	0.41
April	0.31	0.19	0.33	0.33
May	0.38	0.33	0.16	0.20
June	0.14	0.52	0.26	0.24
July	0.23	0.76	0.27	0.22
August	0.18	0.30	0.18	0.18
September	0.25	0.27	0.10	0.15
October	0.38	0.16	0.24	0.17
November	0.23	0.35	0.15	0.15
December	0.07	0.17	0.25	0.16
2008—Max.	9.66	9.18	9.07	9.11
2008—Avg.	8.17	7.73	7.64	7.69
2008—Min.	7.14	7.28	7.19	7.03
2008—S.D.	0.49	0.45	0.34	0.35

Table 6-4. Statistical summary of 2008 Middle River continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Maximums	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	11.26	10.80	10.26	9.17
February	15.26	14.70	14.64	14.32
March	18.70	18.27	18.39	16.77
April	20.94	21.36	21.87	20.96
May	26.20	27.22	26.53	24.69
June	29.75	28.45	28.06	26.16
July	29.39	28.61	30.21	26.68
August	29.19	29.15	27.32	26.38
September	27.24	25.32	26.34	25.59
October	24.37	24.23	24.00	22.79
November	17.13	17.39	17.20	17.47
December	12.68	11.98	12.91	12.92
Averages	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	8.69	8.25	8.03	8.05
February	10.76	10.70	10.28	10.02
March	14.84	14.95	14.52	14.24
April	16.55	16.96	16.74	16.69
May	19.26	20.16	19.88	20.20
June	23.37	23.15	22.96	22.79
July	25.47	25.30	25.05	24.65
August	25.16	25.88	24.37	24.93
September	23.15	22.72	22.98	22.86
October	17.82	18.09	18.14	18.44
November	14.28	14.39	14.68	15.01
December	9.20	8.34	8.79	9.58

Month	Dissolved oxygen (mg/L)			
Maximums	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	11.74	13.24	12.87	13.03
February	12.10	13.27	12.49	11.21
March	19.12	17.61	11.83	11.83
April	15.02	14.15	11.53	11.67
May	18.15	11.31	11.65	9.68
June	19.28	10.94	10.80	9.02
July	16.71	12.27	10.07	8.67
August	14.91	11.32	10.12	9.12
September	23.06	12.95	12.00	9.72
October	16.84	12.19	12.01	11.14
November	14.85	12.54	11.80	10.16
December	12.06	14.33	13.54	12.56
Averages	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	10.00	9.88	10.78	10.69
February	9.92	10.08	10.66	10.12
March	11.76	11.26	10.17	9.91
April	11.45	9.29	9.63	10.07
May	10.00	6.67	7.91	8.23
June	10.19	5.64	7.40	7.40
July	8.72	5.05	7.02	7.22
August	8.43	4.97	7.37	7.49
September	11.71	5.87	8.10	7.85
October	11.52	8.07	9.12	9.15
November	10.62	9.81	9.94	9.26
December	10.73	11.39	11.94	10.74

Month	pH			
Maximums	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	8.08	8.25	8.19	7.87
February	8.30	8.30	8.28	7.88
March	8.89	8.78	8.32	8.28
April	9.40	8.69	8.18	8.22
May	9.16	8.15	8.16	7.95
June	9.43	8.29	8.55	7.94
July	9.51	8.45	8.41	7.83
August	8.97	8.13	8.47	7.88
September	9.37	8.19	8.36	8.00
October	9.09	8.56	9.12	8.52
November	8.95	8.40	8.30	7.93
December	8.28	8.59	8.75	8.62
Averages	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	7.79	7.49	7.69	7.48
February	7.84	7.50	7.83	7.59
March	8.16	8.01	7.72	7.77
April	8.51	7.68	7.74	7.87
May	7.81	7.11	7.75	7.62
June	8.80	7.01	7.50	7.51
July	8.82	7.07	7.29	7.46
August	8.55	7.11	7.48	7.54
September	8.44	7.24	7.62	7.56
October	8.27	7.62	7.70	7.78
November	8.11	7.66	7.84	7.53
December	7.73	7.91	8.11	7.80

Table 6-4 (cont.). Statistical summary of 2008 Middle River continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Minimum	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	5.67	5.39	6.04	7.00
February	7.18	7.61	6.98	7.77
March	11.90	11.45	10.97	11.85
April	13.42	13.63	13.51	14.27
May	15.29	15.29	16.18	17.26
June	18.10	18.51	18.57	19.37
July	22.13	21.65	22.22	23.03
August	22.03	23.38	21.42	23.61
September	19.96	20.60	20.71	20.58
October	12.95	13.28	13.02	15.54
November	11.60	11.86	12.29	12.80
December	5.92	5.52	5.74	7.22
Std. devs.	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	0.86	1.06	0.75	0.43
February	1.68	1.60	1.63	1.35
March	1.38	1.41	1.37	1.06
April	1.69	1.63	1.57	1.36
May	2.03	2.57	2.14	1.66
June	2.21	2.31	2.14	1.73
July	1.63	1.28	1.23	0.66
August	1.38	1.16	1.01	0.55
September	1.37	1.01	1.16	1.13
October	2.61	2.57	2.39	2.01
November	1.25	1.34	1.18	1.08
December	1.57	1.73	2.06	1.75
2008—Max.	29.75	29.15	30.21	26.68
2008—Avg.	17.39	17.42	17.55	17.30
2008—Min.	5.67	5.39	5.74	7.00
2008—S.D.	6.04	6.24	5.90	5.90

Month	Dissolved oxygen (mg/L)			
Minimum	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	7.23	6.91	8.95	9.65
February	7.82	7.51	9.17	8.92
March	7.60	7.46	8.80	8.90
April	7.93	5.00	6.58	8.08
May	4.88	2.02	5.94	6.41
June	0.49	0.57	3.83	5.97
July	1.31	0.69	5.06	5.67
August	2.58	0.89	5.17	5.61
September	4.94	1.15	3.05	5.37
October	8.75	3.50	2.93	6.99
November	7.78	7.35	6.60	7.58
December	7.82	7.83	9.27	9.05
Std. devs.	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	0.88	1.46	0.65	0.60
February	0.79	1.22	0.52	0.45
March	1.97	1.83	0.66	0.54
April	1.72	1.55	0.69	0.63
May	1.68	1.73	0.67	0.65
June	3.13	1.89	0.87	0.67
July	2.89	1.80	0.80	0.37
August	2.40	1.72	0.73	0.46
September	3.14	2.14	0.92	0.53
October	1.51	2.00	1.24	0.65
November	1.28	0.96	0.81	0.40
December	1.57	1.13	0.80	0.96
2008—Max.	23.06	17.61	13.54	13.03
2008—Avg.	10.28	8.11	9.06	9.01
2008—Min.	0.49	0.57	2.93	5.37
2008—S.D.	2.32	2.88	1.66	1.40

Month	pH			
Minimum	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	7.15	6.91	7.28	7.26
February	7.54	7.17	7.42	7.36
March	7.65	7.44	7.11	7.49
April	7.44	6.87	7.39	7.48
May	7.06	6.58	7.36	7.30
June	7.81	6.60	7.15	7.17
July	7.78	6.75	7.03	7.21
August	7.73	6.83	7.08	7.28
September	7.67	6.87	7.01	7.37
October	7.46	7.05	7.21	7.30
November	7.63	7.20	7.25	7.30
December	7.39	7.33	7.81	7.29
Std. devs.	Undine Road	Howard Road	Near Tracy Boulevard	Union Point
January	0.19	0.23	0.18	0.14
February	0.14	0.28	0.14	0.08
March	0.29	0.30	0.20	0.16
April	0.38	0.28	0.13	0.13
May	0.43	0.21	0.12	0.12
June	0.43	0.25	0.21	0.19
July	0.25	0.31	0.19	0.10
August	0.26	0.21	0.18	0.09
September	0.20	0.23	0.21	0.06
October	0.33	0.32	0.38	0.26
November	0.27	0.21	0.22	0.16
December	0.17	0.33	0.22	0.46
2008—Max.	9.51	8.78	9.12	8.62
2008—Avg.	8.09	7.34	7.64	7.60
2008—Min.	7.06	6.58	7.01	7.17
2008—S.D.	0.50	0.44	0.29	0.26

Table 6-5. Statistical summary of 2008 Grant Line Canal continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	10.88	10.61	10.87	10.94
February	14.66	14.57	14.57	14.10
March	17.04	17.07	17.03	16.96
April	20.15	19.99	20.01	19.47
May	24.37	24.15	24.01	23.94
June	27.36	27.11	26.97	26.72
July	28.97	29.34	28.04	28.82
August	29.16	28.52	27.60	26.66
September	27.90	26.30	26.23	25.81
October	25.38	25.00	22.63	23.79
November	17.54	16.53	17.56	17.49
December	12.42	13.16	11.99	13.32
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	8.83	8.82	8.98	8.63
February	11.16	11.21	11.23	10.79
March	14.97	15.05	15.01	14.85
April	16.60	16.51	16.45	16.44
May	19.40	19.37	19.35	19.44
June	23.24	23.18	23.15	22.75
July	25.30	25.25	24.76	24.75
August	25.26	24.86	24.90	24.71
September	23.46	23.34	22.88	22.98
October	18.41	18.53	17.39	18.38
November	15.22	14.27	15.51	15.07
December	9.05	9.49	8.98	9.35

Month	Dissolved oxygen (mg/L)			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	11.64	11.99	12.14	11.48
February	13.54	11.74	11.47	11.01
March	15.17	14.07	14.68	12.56
April	17.52	16.56	17.54	14.71
May	17.79	16.17	17.68	11.56
June	14.70	14.00	13.44	10.02
July	15.86	15.13	11.39	12.85
August	13.56	13.11	9.86	8.12
September	17.90	18.57	16.48	8.91
October	15.47	15.16	15.57	10.18
November	14.17	13.77	12.30	13.65
December	12.87	12.25	11.69	12.03
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	10.25	10.82	10.40	9.77
February	10.89	10.10	10.03	9.76
March	11.89	11.61	11.56	10.03
April	12.56	12.60	12.76	10.63
May	10.63	10.23	10.36	8.07
June	8.20	7.15	6.06	5.98
July	6.25	5.21	4.79	6.62
August	6.54	5.03	4.72	6.81
September	9.96	7.72	7.81	7.27
October	10.44	8.98	9.88	8.60
November	10.67	10.81	8.83	9.77
December	11.68	11.13	10.69	10.65

Month	pH			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	8.18	8.07	8.15	7.89
February	8.27	7.92	8.10	8.03
March	8.82	8.85	8.69	8.65
April	9.07	9.22	9.12	9.03
May	9.13	9.10	9.04	8.51
June	9.17	9.29	9.20	8.99
July	9.13	9.23	8.96	8.76
August	8.86	8.81	8.56	7.59
September	8.94	9.19	8.76	7.88
October	8.91	8.89	8.67	7.97
November	8.60	8.56	8.28	8.15
December	8.48	8.32	7.97	8.00
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	7.78	7.85	7.84	7.58
February	7.85	7.64	7.86	7.75
March	8.33	8.21	8.29	7.93
April	8.48	8.50	8.61	8.38
May	8.01	7.97	8.05	7.40
June	8.29	8.07	8.03	7.58
July	8.28	8.08	8.06	7.50
August	8.20	7.89	7.76	7.22
September	8.24	8.06	8.01	7.57
October	8.13	7.92	7.79	7.58
November	8.05	7.94	7.74	7.66
December	8.30	8.09	7.62	7.62

Table 6-5 (cont.). Statistical summary of 2008 Grant Line Canal continuous water temperature, dissolved oxygen, and pH data

Month	Water temperature (°C)			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	7.41	7.55	7.44	7.15
February	8.39	8.41	8.56	8.11
March	12.75	13.16	13.17	12.42
April	14.30	14.39	14.33	14.47
May	16.31	16.39	16.38	16.46
June	19.18	19.03	19.15	19.00
July	22.54	22.98	22.58	22.74
August	22.87	22.33	22.84	22.84
September	20.72	20.86	19.56	20.64
October	13.70	14.32	12.46	15.65
November	13.25	12.60	12.65	12.62
December	6.71	7.01	7.04	6.65
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	0.64	0.66	0.73	0.75
February	1.49	1.51	1.51	1.46
March	0.96	0.86	0.86	0.96
April	1.30	1.30	1.28	1.13
May	1.85	1.85	1.83	1.79
June	1.90	1.93	1.83	1.86
July	1.39	1.35	1.11	0.94
August	1.17	1.12	0.95	0.67
September	1.43	1.20	1.58	1.16
October	2.61	2.87	2.41	2.16
November	1.04	1.21	1.73	1.09
December	1.34	1.64	1.21	1.98
2008—Max.	29.16	29.34	28.04	28.82
2008—Avg.	17.83	17.61	17.63	17.36
2008—Min.	6.71	7.01	7.04	6.65
2008—S.D.	6.00	5.98	5.84	5.74

Month	Dissolved oxygen (mg/L)			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	8.06	9.05	9.17	8.17
February	8.08	8.19	8.73	8.35
March	8.48	8.64	8.73	7.81
April	9.66	10.20	10.03	7.95
May	8.89	7.87	7.60	4.35
June	1.20	0.82	0.89	1.08
July	1.05	0.56	1.05	3.91
August	2.54	1.34	1.49	4.34
September	2.55	2.40	4.33	4.49
October	7.15	4.73	6.50	5.19
November	7.41	8.44	6.87	6.49
December	9.68	9.37	9.45	8.88
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	0.61	0.72	0.78	0.74
February	1.10	0.63	0.52	0.53
March	1.28	1.12	1.12	1.04
April	1.31	1.15	1.36	1.28
May	1.18	1.18	1.27	1.12
June	3.13	3.38	2.70	1.69
July	2.57	2.53	1.72	0.86
August	1.94	1.72	1.34	0.66
September	2.50	2.22	2.00	0.94
October	1.34	1.48	1.64	0.97
November	1.74	0.89	1.47	1.22
December	0.81	0.79	0.51	0.57
2008—Max.	17.90	18.57	17.68	14.71
2008—Avg.	9.93	9.22	8.98	8.66
2008—Min.	1.05	0.56	0.89	1.08
2008—S.D.	2.66	2.98	3.00	1.89

Month	pH			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	7.35	7.66	7.61	7.29
February	7.28	7.17	7.65	7.21
March	7.83	7.59	7.79	7.28
April	7.83	7.75	8.06	7.79
May	7.45	7.46	7.46	6.74
June	7.40	7.27	7.32	7.24
July	7.63	7.46	7.38	7.25
August	7.74	7.55	7.49	6.98
September	7.62	7.51	7.63	6.98
October	7.56	7.40	7.23	7.27
November	7.71	7.59	7.44	7.17
December	8.04	7.68	7.23	7.20
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	0.18	0.12	0.16	0.13
February	0.22	0.15	0.12	0.16
March	0.21	0.30	0.21	0.36
April	0.25	0.28	0.25	0.34
May	0.34	0.34	0.31	0.34
June	0.42	0.56	0.54	0.36
July	0.32	0.39	0.34	0.17
August	0.21	0.24	0.19	0.14
September	0.25	0.28	0.22	0.21
October	0.28	0.25	0.25	0.15
November	0.22	0.19	0.17	0.21
December	0.07	0.12	0.16	0.25
2008—Max.	9.17	9.29	9.20	9.03
2008—Avg.	8.14	7.98	7.91	7.65
2008—Min.	7.28	7.17	7.23	6.74
2008—S.D.	0.34	0.38	0.39	0.37

Spring (March–May 2008). A maximum DO concentration of 20.23 mg/L was measured on March 24 at Old River upstream of the ORT barrier, and a minimum of 2.02 mg/L was recorded on May 19 at Middle River at Howard Road. Monthly mean DO concentrations during this time period ranged from 6.67 mg/L in May at Middle River at Howard Road to 13.70 mg/L in March at Old River at Tracy Wildlife Association. The expected range of DO values in the spring (assuming 100% saturation) based on water temperature, salinity, and local barometric pressure was between 7.89 mg/L and 10.97 mg/L. Actual DO saturation values ranged from 25% to 213% (2.02–20.23 mg/L). There were 2 stations that recorded at least 1 daily DO concentration below 5.0 mg/L: Middle River at Howard Road and Old River at Tracy Wildlife Association.

Summer (June–August 2008). A maximum DO concentration of 19.85 mg/L was measured on July 15, and a minimum of 0.40 mg/L was recorded on June 19 at Old River at Tracy Wildlife Association. Monthly mean DO concentrations during this time period ranged from 4.72 mg/L in August at Grant Line Canal at Tracy Boulevard to 12.99 mg/L in June at Old River near head. The expected range of DO values in the summer (assuming 100% saturation) based on water temperature, salinity, and local barometric pressure was between 7.49 mg/L and 9.39 mg/L. Actual DO saturation values ranged from 4.8% to 255% (0.62–23.16 mg/L). Eight of the 13 stations had at least 1 daily DO concentration of less than 5.0 mg/L, with the exceptions being Old River near head, Middle River at Undine Road, Middle River near Tracy Boulevard, Middle River at Union Point, and Victoria Canal.

Fall (September–November 2008). A maximum DO concentration of 23.06 mg/L was measured on September 24 at Middle River at Undine Road, and a minimum of 1.15 mg/L was recorded on September 1 at Middle River at Howard Road. Monthly mean DO concentrations during this time period ranged from 5.48 mg/L in September at Old River above the ORT barrier to 12.42 mg/L in September at Old River at head. The expected range of DO values in the fall (assuming 100% saturation) based on water temperature, salinity, and local barometric pressure was between 7.80 mg/L and 10.81 mg/L. Actual DO saturation values ranged from 11% to 273% (1.15–23.06 mg/L). Three of the 13 stations had at least 1 daily DO concentration of less than 5.0 mg/L: Middle River at Howard Road, Old River upstream of the ORT barrier, and Old River downstream of the ORT barrier.

ANOVA Analysis

Old River. ANOVA was performed on average daily DO concentrations data to determine whether monthly mean concentrations in June, July, August, and September differed among 4 Old River monitoring locations (near head, at the Tracy Wildlife Association, upstream of the ORT barrier, and downstream of the ORT barrier).

Test results showed that at least 1 mean was significantly different in June, July, August, and September.

June: **($F(3,116)=89$, $p < 0.01$)**

July: **($F(3,120)=73$, $p < 0.01$)**

August: **($F(3,120)=104$, $p < 0.01$)**

September: **($F(3,116)=166$, $p < 0.01$).**

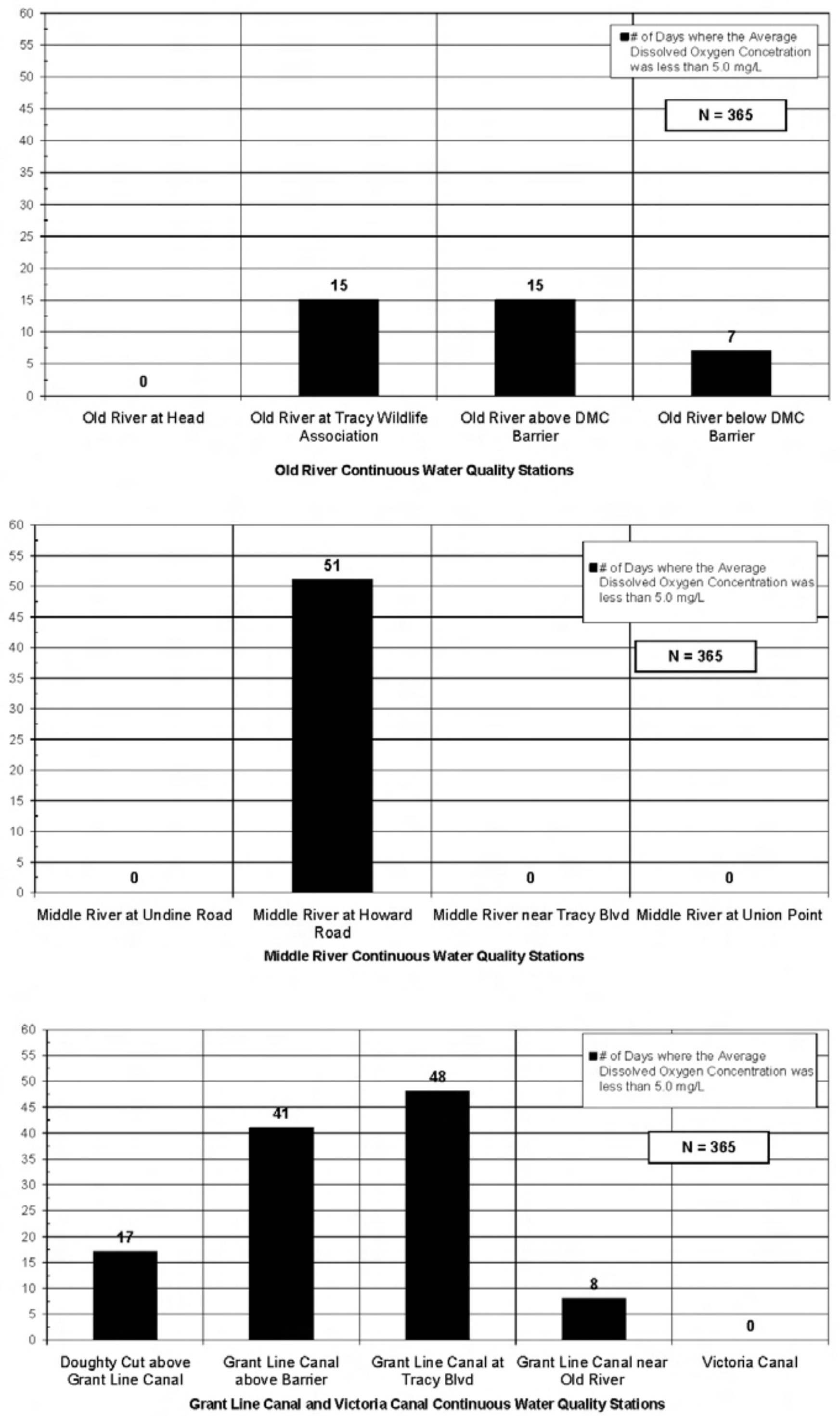
Explanation of $F(3,116)=89$, $p < 0.01$:
$F(3,116)$ refers to the between-groups degrees of freedom (3) and the within-groups degrees of freedom (116). The F-statistic (89) and p-value (< 0.01) were calculated from the ANOVA test. Statistical significance was based on having a p-value of less than 0.01.

Tukey's HSD test was then performed to determine which mean site concentrations differed. In June, July, August, and September, DO concentrations were significantly less ($p < 0.01$) at Old River at Tracy Wildlife Association, Old River upstream of the ORT barrier, and Old River downstream of the ORT barrier in comparison with Old River at head. In September, DO concentrations at the sites near the barrier were significantly less than at Old River near head and Old River at Tracy Wildlife Association. There were no significant differences ($p > 0.01$) in DO concentrations between the sites upstream and downstream of the ORT barrier.

In 2008, the total number of days where the average DO concentrations was less than 5.0 mg/L at each site ranged from 0 to 4.1%. These included 15 days (4.1%, upstream of the ORT barrier), 7 days (1.9%, downstream of the ORT barrier), and 15 days (4.1%, Old River at Tracy Wildlife Association) where average DO concentrations were below 5 mg/L (Figure 6-20).

There were no average daily DO concentrations less than 5 mg/L at Old River near head. In 2007, there were 19 days (Old River upstream of the ORT barrier), 11 days (Old River downstream of the ORT barrier), and 4 days (Old River at Tracy Wildlife Association) where daily average DO concentrations were less than 5 mg/L.

Figure 6-20. Number of days where the average dissolved oxygen concentration was less than 5.0 mg/L at each Old River, Middle River, and Grant Line Canal continuous monitoring site



Middle River. ANOVA was performed on average daily DO concentration data to determine whether monthly mean concentrations in June, July, and August differed among 4 Middle River monitoring locations (Middle River at Undine Road, Middle River at Howard Road, Middle River near Tracy Boulevard, and Middle River at Union Point). Test results showed that at least 1 mean was significantly different in June, July, and August.

June: **$(F(3,116)=57, p < 0.01)$**

July: **$(F(3,120)=99, p < 0.001)$**

August: **$(F(3,120)=106, p < 0.01)$**

Tukey's HSD test was then performed to determine which mean site concentrations differed. In June, July, and August, DO concentrations were significantly less ($p < 0.01$) at Middle River at Howard Road in comparison with each of the other 3 Middle River sites. Middle River at Undine Road had significantly higher concentrations ($p < 0.01$) than the other 3 Middle River sites during June, July, and August. There were no significant differences ($p > 0.01$) in DO concentrations between Middle River near Tracy Boulevard and Middle River at Union Point.

In 2008, the total number of days where the average DO concentration was less than 5.0 mg/L at each site ranged from 0 to 14%. There were 51 days (14%) at Middle River at Howard Road where average daily DO concentrations were below 5 mg/L (see Figure 6-20). There were no days where the average daily DO concentration was less than 5.0 mg/L at the other 3 Middle River sites.

In 2007, there were 12 days at Middle River at Howard Road where the average daily DO concentration was below 5 mg/L.

Grant Line Canal. ANOVA was performed on average daily DO concentration data to determine whether monthly mean concentrations in June, July, and August differed among 4 Grant Line Canal monitoring locations (Doughty Cut above Grant Line Canal, Grant Line Canal above barrier, Grant Line Canal at Tracy Boulevard, and Grant Line Canal near Old River). Test results showed that at least 1 mean was significantly different in June, July, and August.

June: **$(F(3,116)=5.3, p < 0.01)$**

July: **$(F(3,120)=11.1, p < 0.01)$**

August: **$(F(3,119)=29.5, p < 0.01)$**

Tukey's HSD test was then performed to determine which mean site concentrations differed. The results showed that DO concentrations were significantly higher ($p < 0.01$) at Doughty Cut above Grant Line Canal in June compared with Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River. Grant Line Canal above barrier and Grant Line Canal at Tracy Boulevard had significantly lower ($p > 0.01$) DO concentrations than the other 2 Grant Line Canal sites in July and August.

In 2008, the total number of days where the average DO concentration was less than 5.0 mg/L at each site ranged from 2.2% to 13.2%. There were 17 days (4.7%, Doughty Cut above Grant Line Canal), 41 days (11.2%, Grant Line Canal above barrier), 48 days (13.2%, Grant Line Canal at Tracy Boulevard), and 8 days (2.2%, Grant Line Canal near Old River) where average daily DO concentrations were below 5 mg/L (see Figure 6-20).

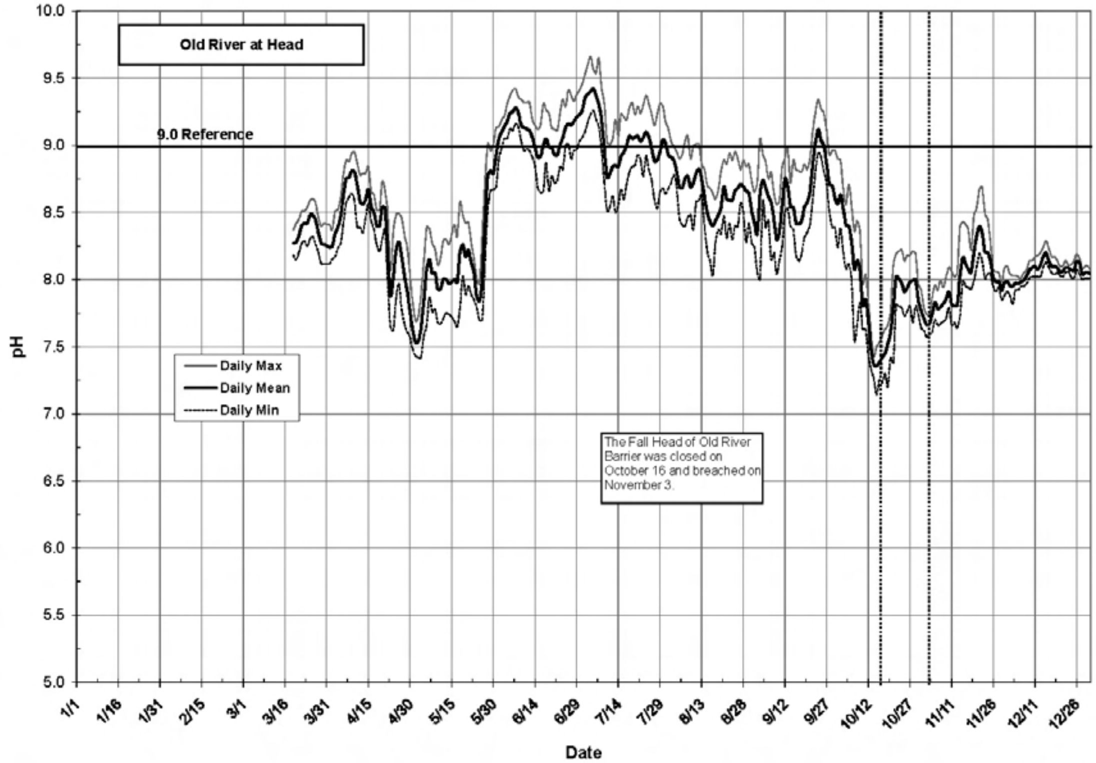
In 2007, there were 10 days (Grant Line Canal above barrier) and 17 days (Grant Line Canal at Tracy Boulevard) where daily average DO concentrations were below 5 mg/L (see Figure 6-15).

pH

pH is a measure of the hydrogen ion concentration $[H^+]$ of a solution. pH values range from 1 to 14, with values less than 7 considered acidic and values greater than 7 considered basic. Because the pH scale is logarithmic, a pH value of 7 is 10 times greater than a pH value of 6 and is 100 times greater than a value of 5. Natural waters usually have pH values in the range of 4 to 9, and most are slightly basic (American Public Health Association 2005). The EPA-recommended criterion for pH is an instantaneous maximum between 6.5 and 9.0 (Marshack 2000).

A maximum pH of 9.66 was recorded on July 4 at Old River near head, and a minimum of 6.58 was recorded on May 19 at Middle River at Howard Road (Figures 6-21 to 6-27 and Tables 6-3 to 6-5). pH values were highest from April through August, especially in June and July at Old River at head, where the monthly pH averages were greater than 9.0. Recorded pH values of 9.0 or greater were more prevalent at the upstream sites on Old River, Middle River, and Grant Line Canal. In 2007, there were 4,127 (Old River near head), 3,328 (Middle River at Undine Road), and 1,047 (Grant Line Canal above barrier) readings where the sonde(s) recorded pH values of 9.0 or greater, while the other 10 stations had a combined total of 1,302 readings (Figure 6-28). The downstream monitoring sites had the fewest occurrences of pH values of 9.0 or higher: Old River below the ORT barrier (87), Middle River at Union Point (0), Grant Line Canal near Old River (31), and Victoria Canal (0).

Figure 6-21. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) pH data



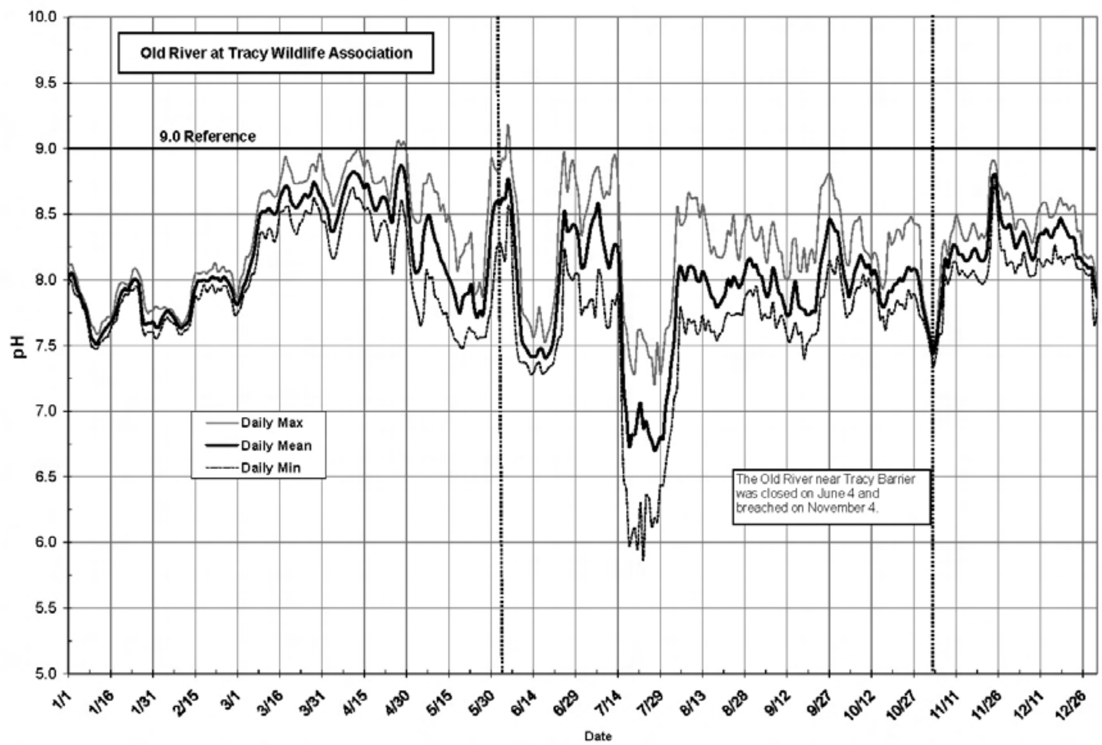
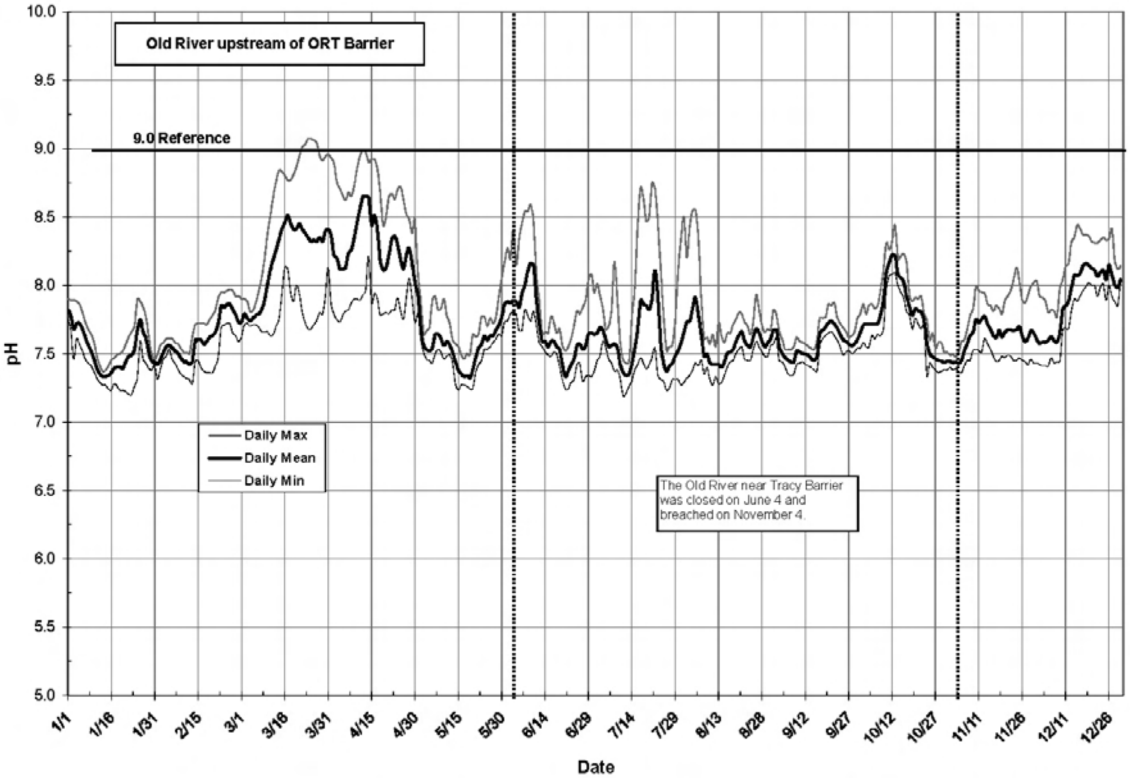


Figure 6-22. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) pH data



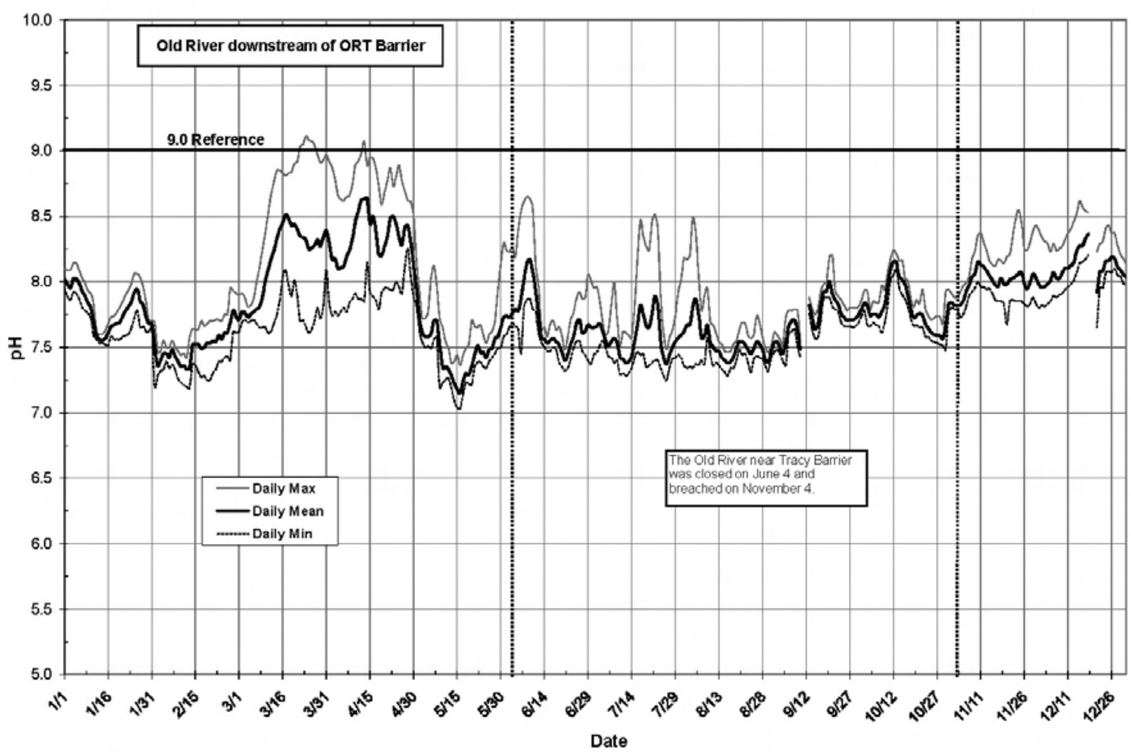
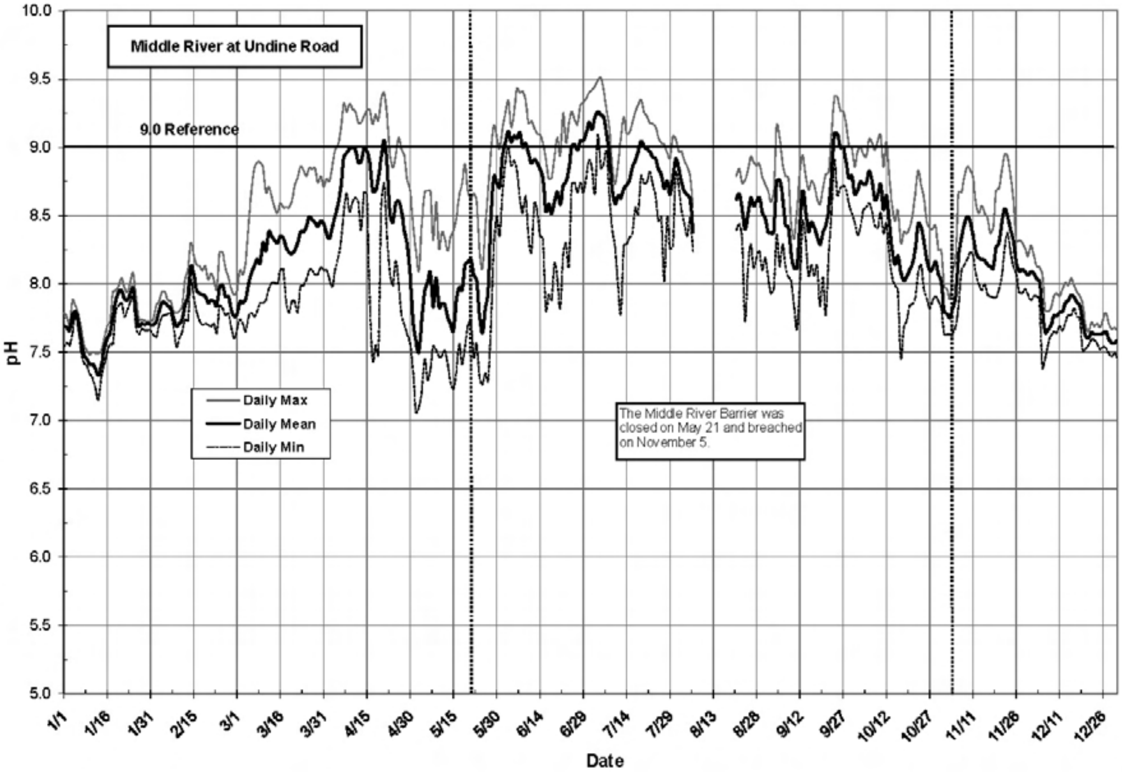


Figure 6-23. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) pH data



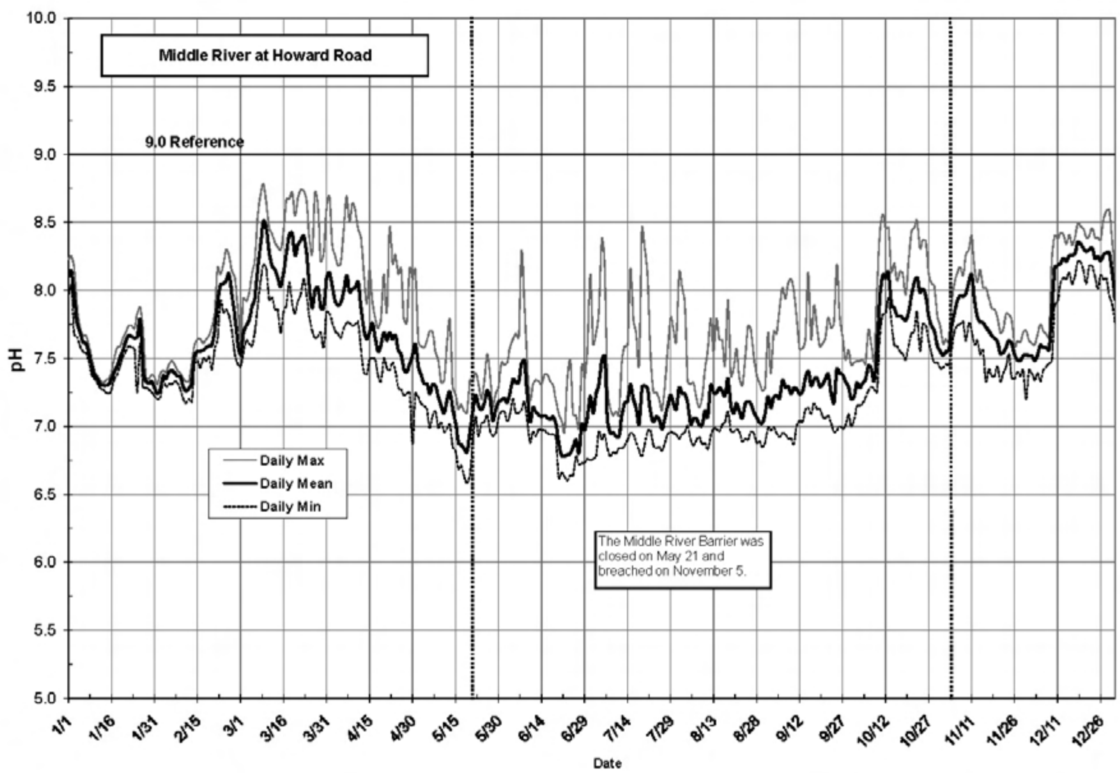
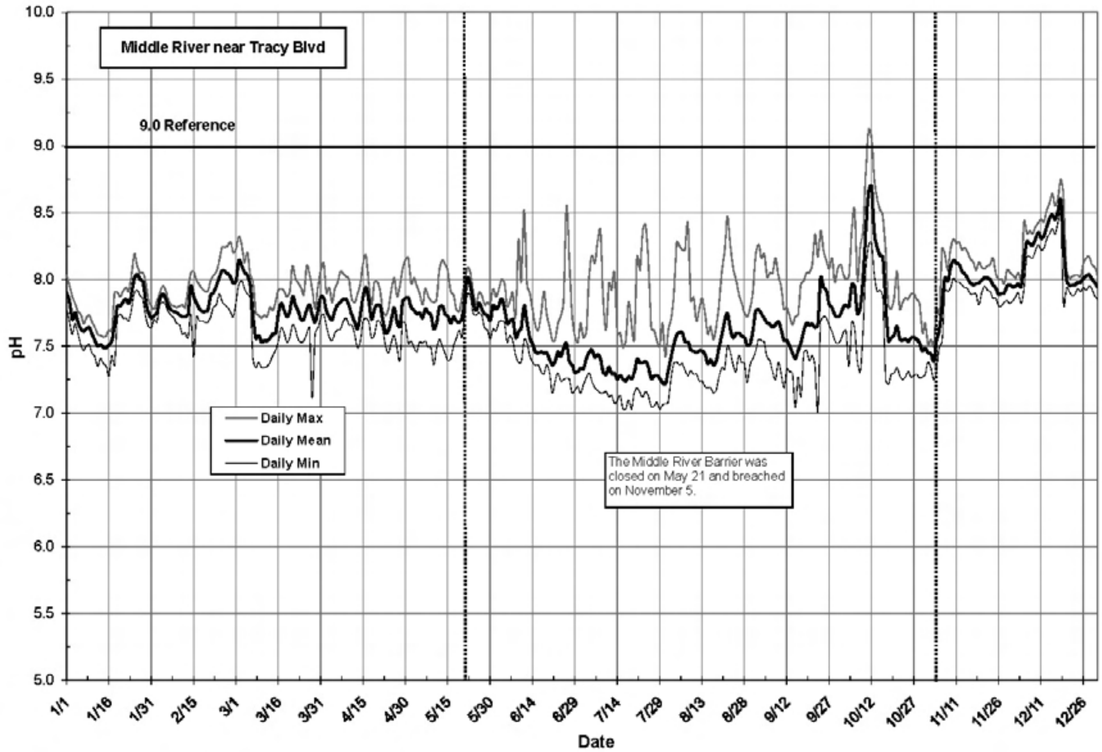


Figure 6-24. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) pH data



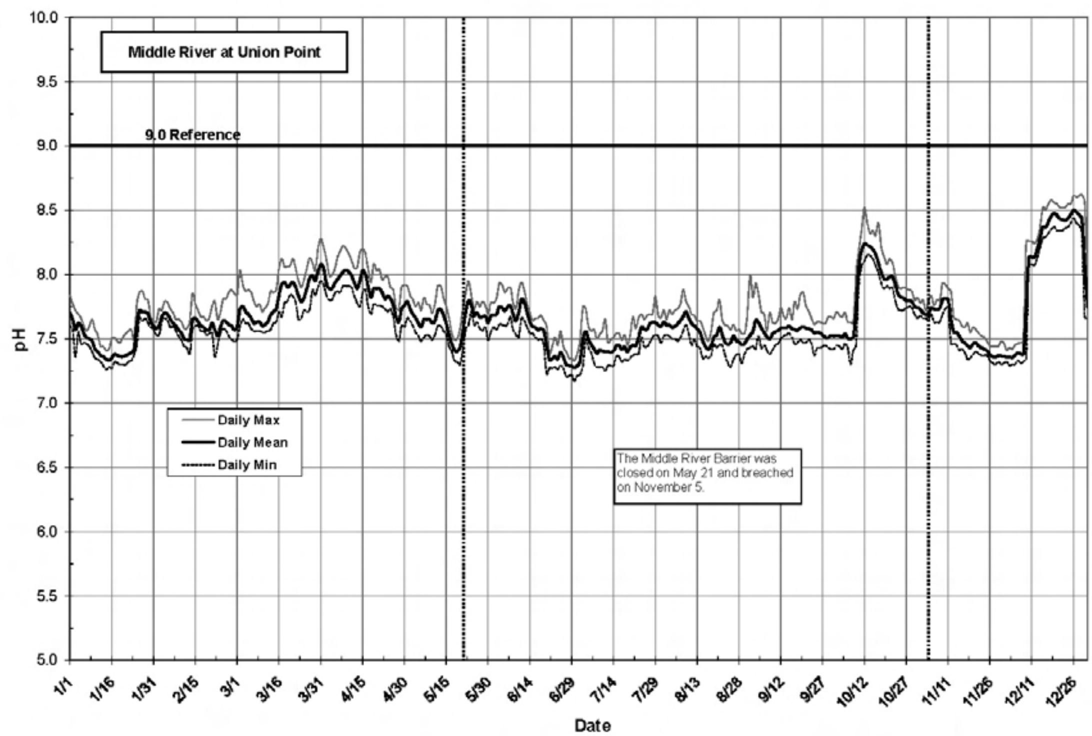
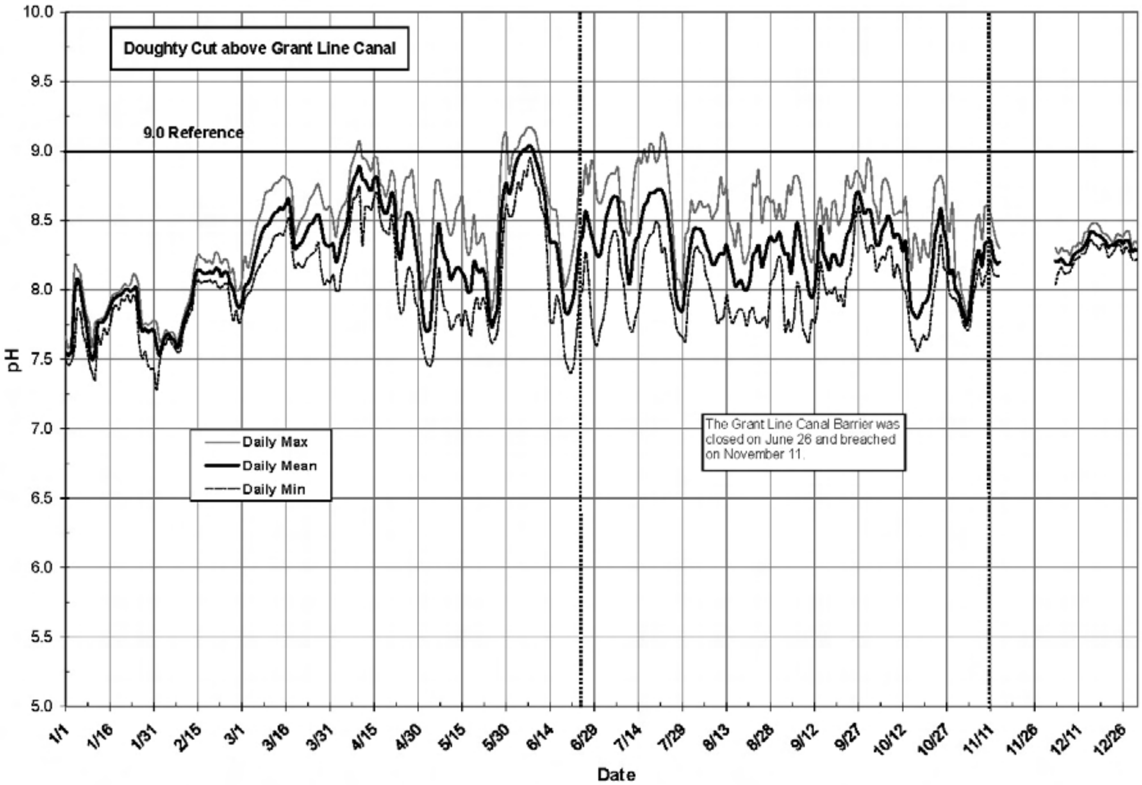


Figure 6-25. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) pH data



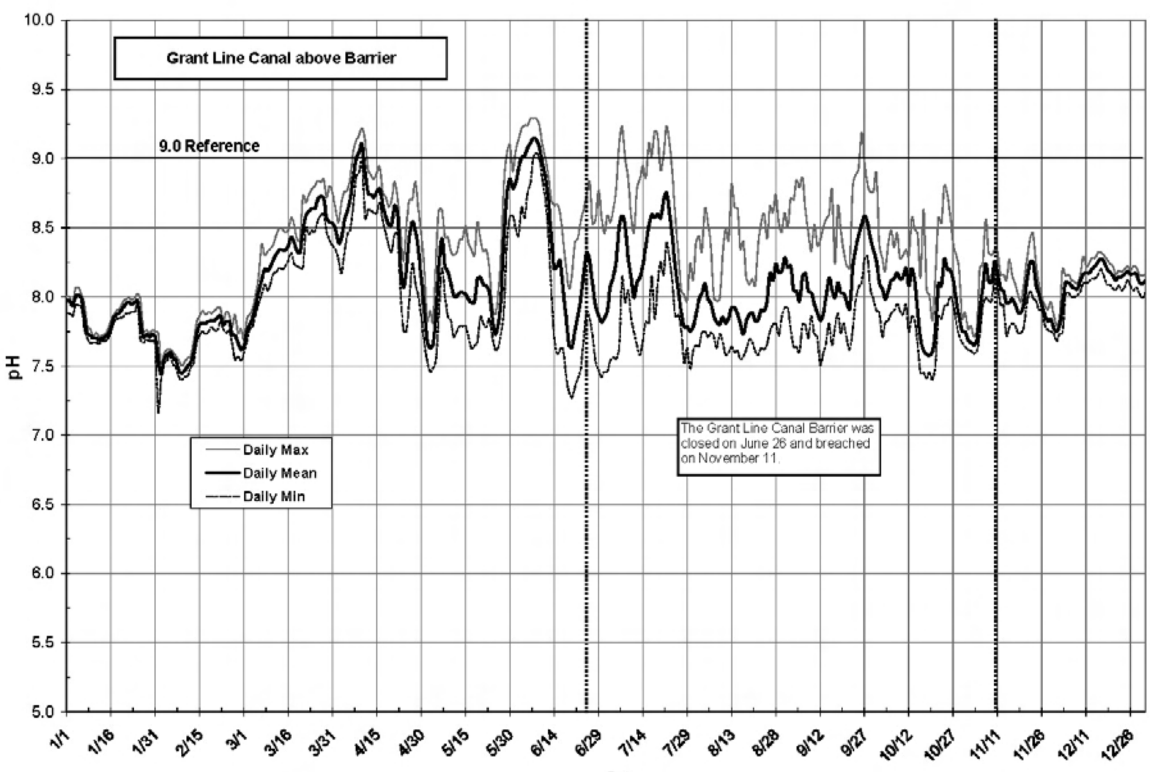
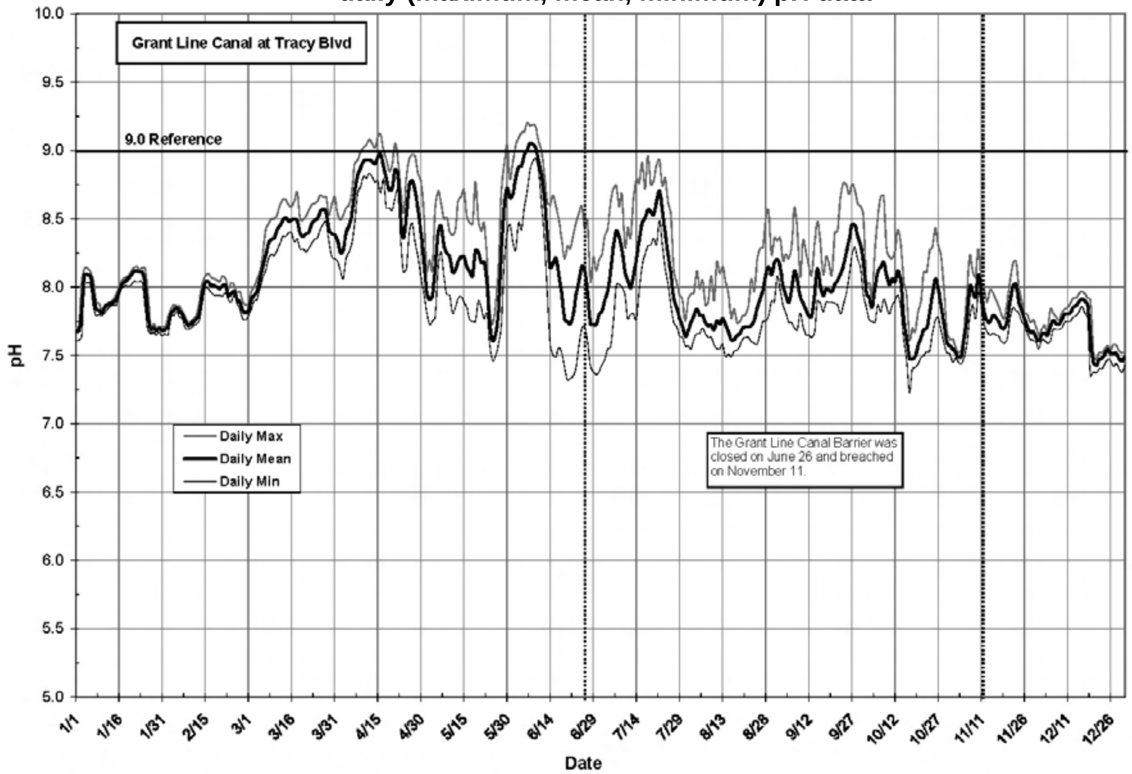


Figure 6-26. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) pH data



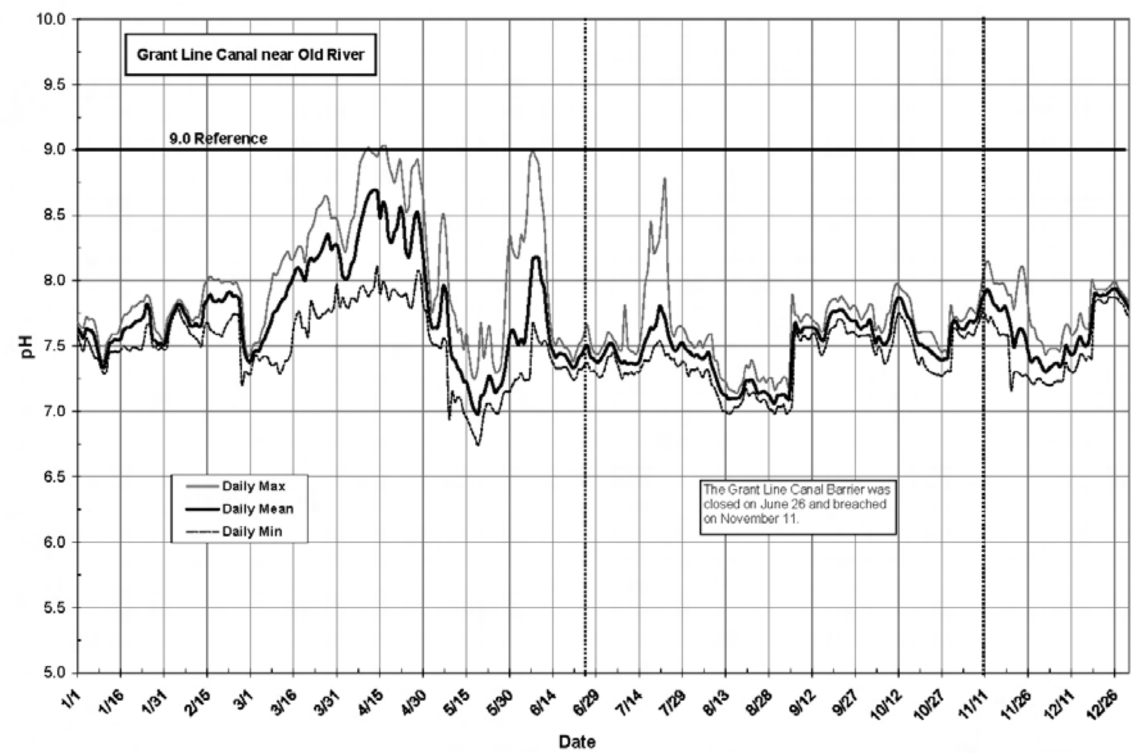


Figure 6-27. Victoria Canal daily (maximum, mean, minimum) pH data

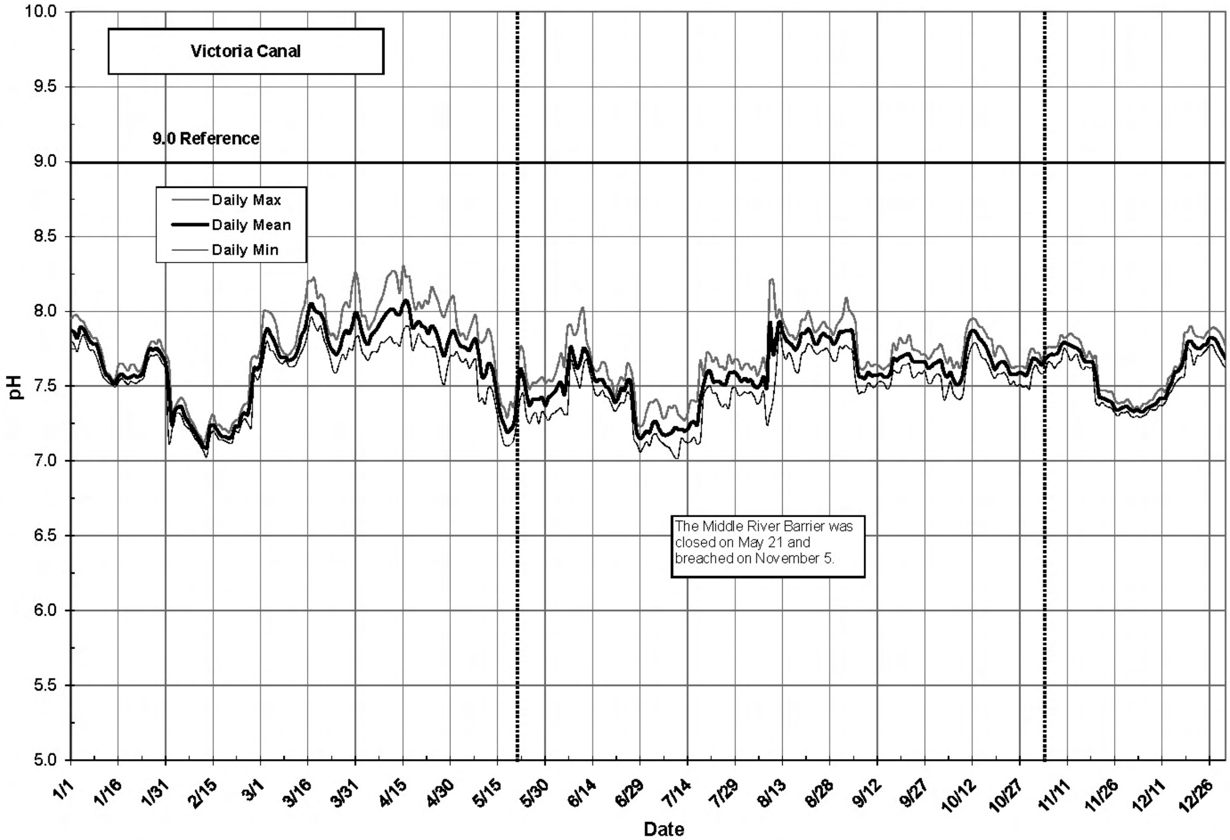
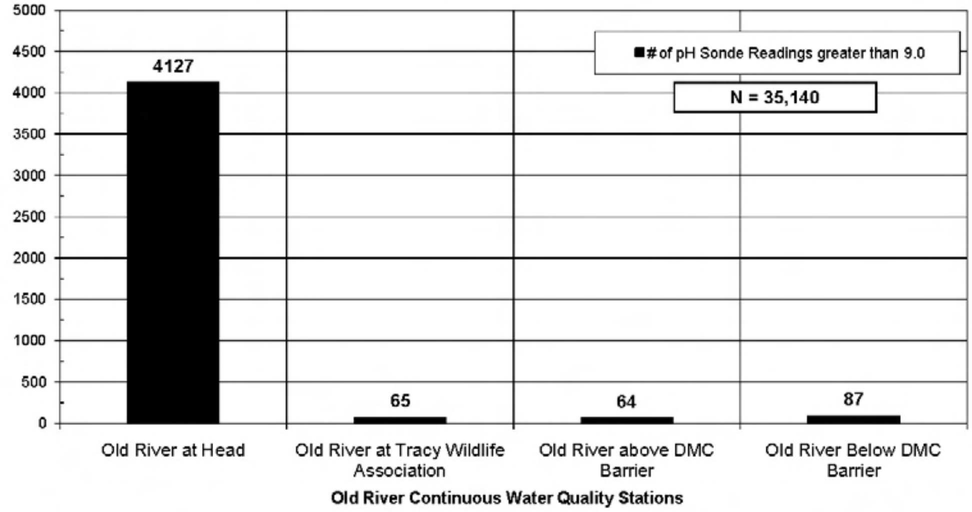
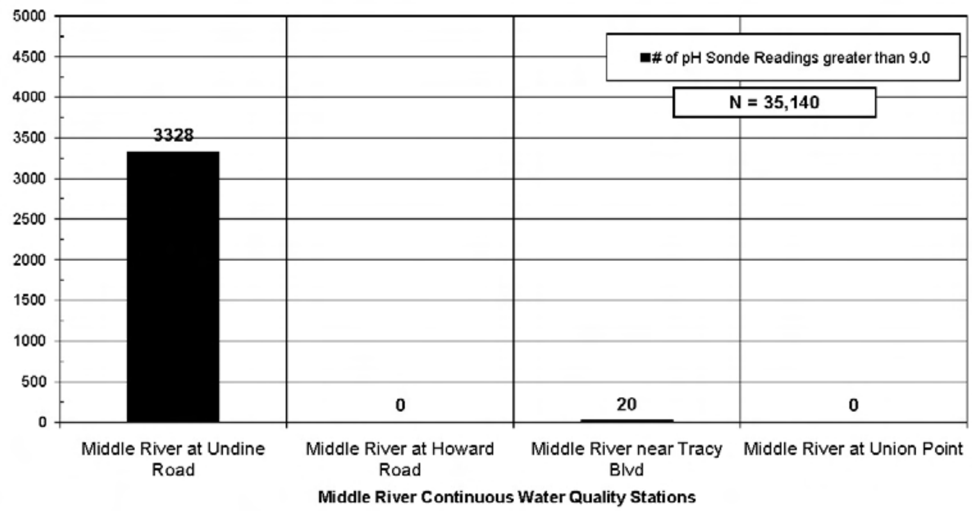
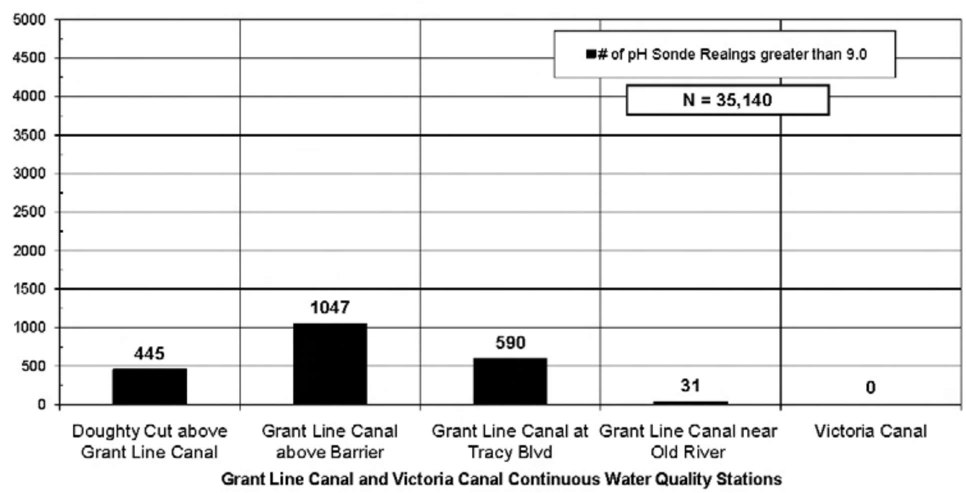


Figure 6-28. Number of pH readings greater than 9.0 at each Old River, Middle River, and Grant Line Canal continuous monitoring site





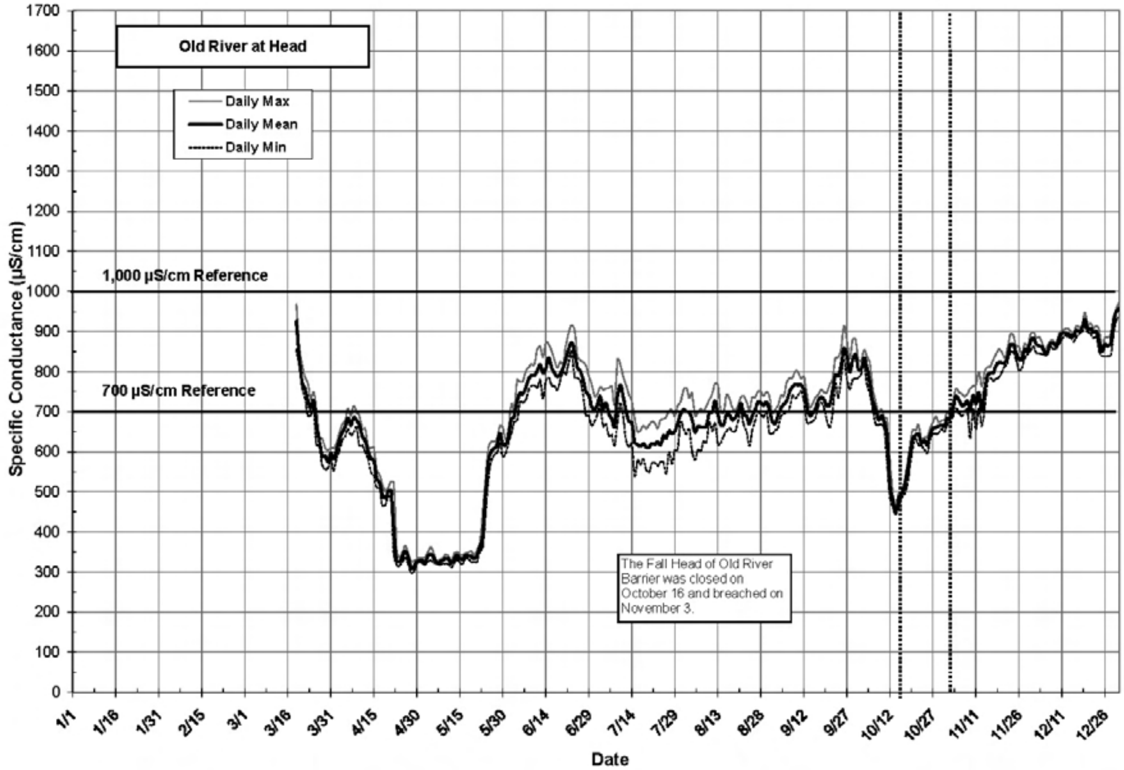


Specific Conductance

Conductivity is a measure of the ability of an aqueous solution to carry an electrical current (American Public Health Association 2005). Specific conductance values are temperature compensated to 25 ºC and can be used to estimate salinity and total dissolved solids (TDS) (Wagner et al. 2006). Specific conductance is of vital importance in the south Delta because the water is used for irrigation. High amounts of dissolved salts in irrigation water can result in crop damage and reduced yield. The State Water Board has specific conductivity objectives for 3 sites in the south Delta: San Joaquin River at Brandt Bridge, Old River near Middle River, and Old River at Tracy Road Bridge. The 30-day running average for these sites is not supposed to exceed 700 µS/cm from April 1 to August 31 and 1,000 µS/cm from September 1 to March 31.

April–August 2008, Agricultural Season. A maximum of 1,231.4 µS/cm was recorded on June 9 at Middle River at Howard Road (Figures 6-29 to 6-35 and Tables 6-6 to 6-9). The minimum recorded specific conductance was 241.6 µS/cm on July 15 at Middle River at Union Point. Monthly mean values for this time period ranged from 275.7 µS/cm in July at Middle River at Union Point to 957.3 µS/cm in June at Old River at Tracy Wildlife Association. Eight of the 13 monitoring sites had at least 1 month where specific conductance averaged 700 µS/cm or higher. Mean conductance values were highest at these 8 stations in June and July. Old River at Tracy Wildlife Association had the highest monthly average conductance values in every month during this time period. The 5 stations that did not have a month where conductance values averaged more than 700 uS/cm were Middle River at Howard Road, Middle River near Tracy Boulevard, Middle River at Union Point, Victoria Canal, and Grant Line Canal near Old River.

Figure 6-29. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) specific conductance data



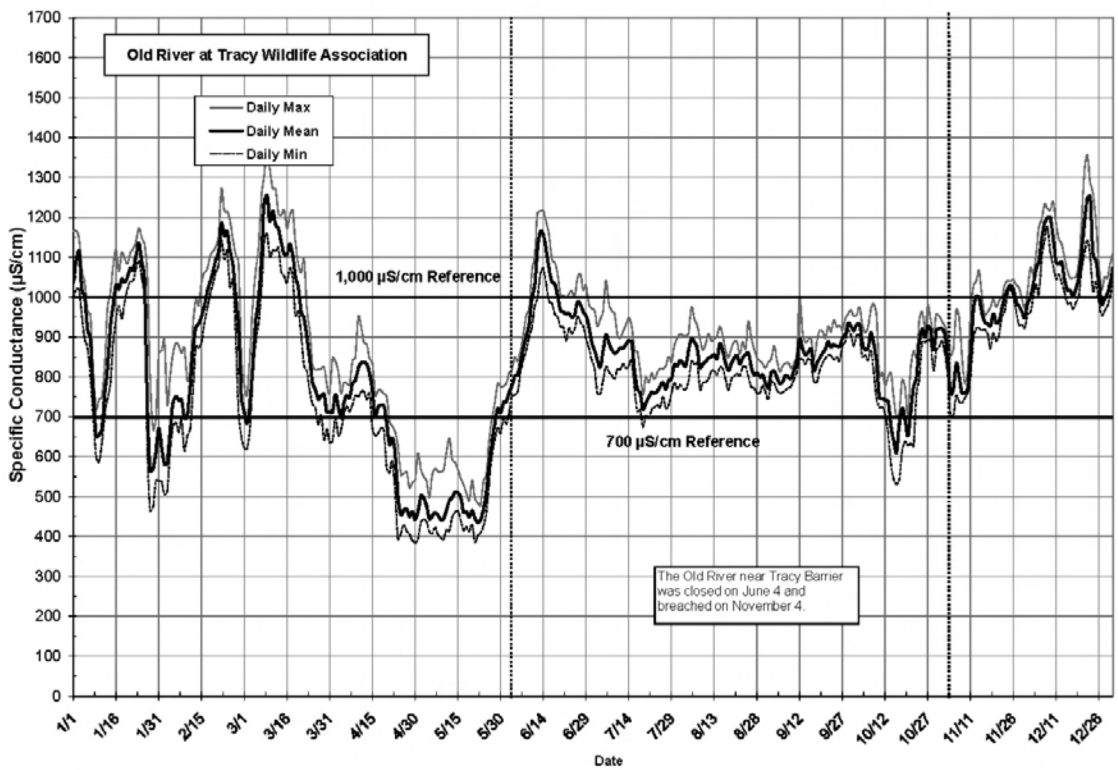
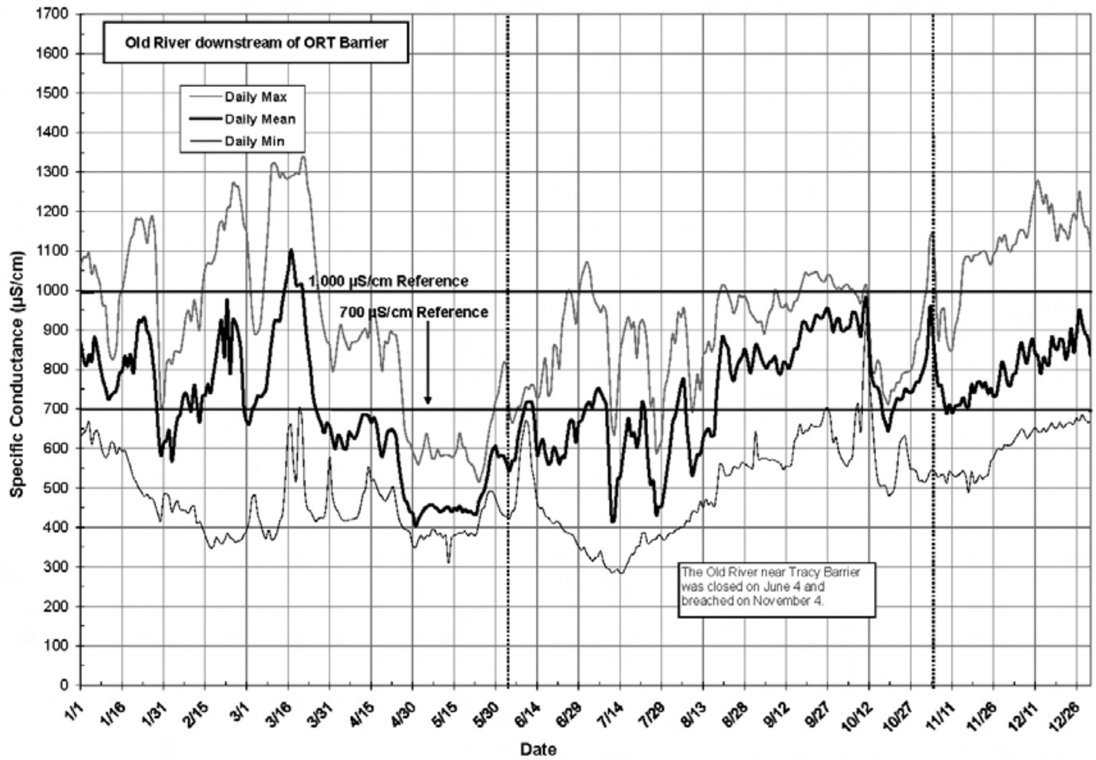


Figure 6-30. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) specific conductance data



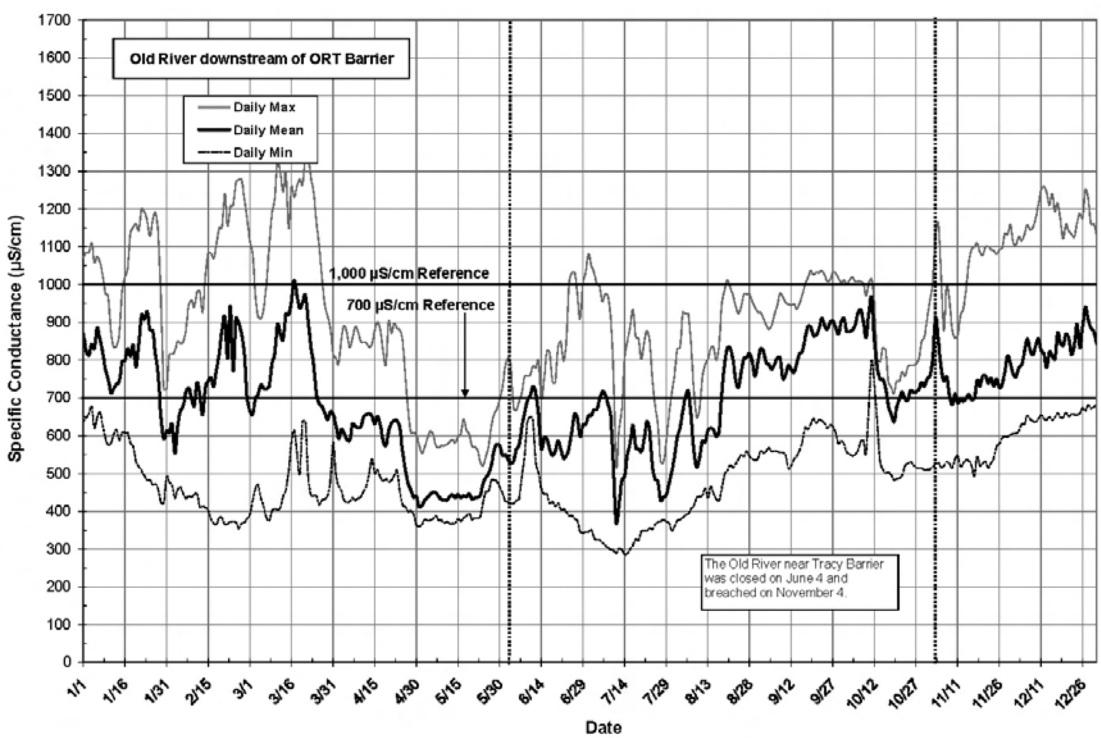


Figure 6-31. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) specific conductance data

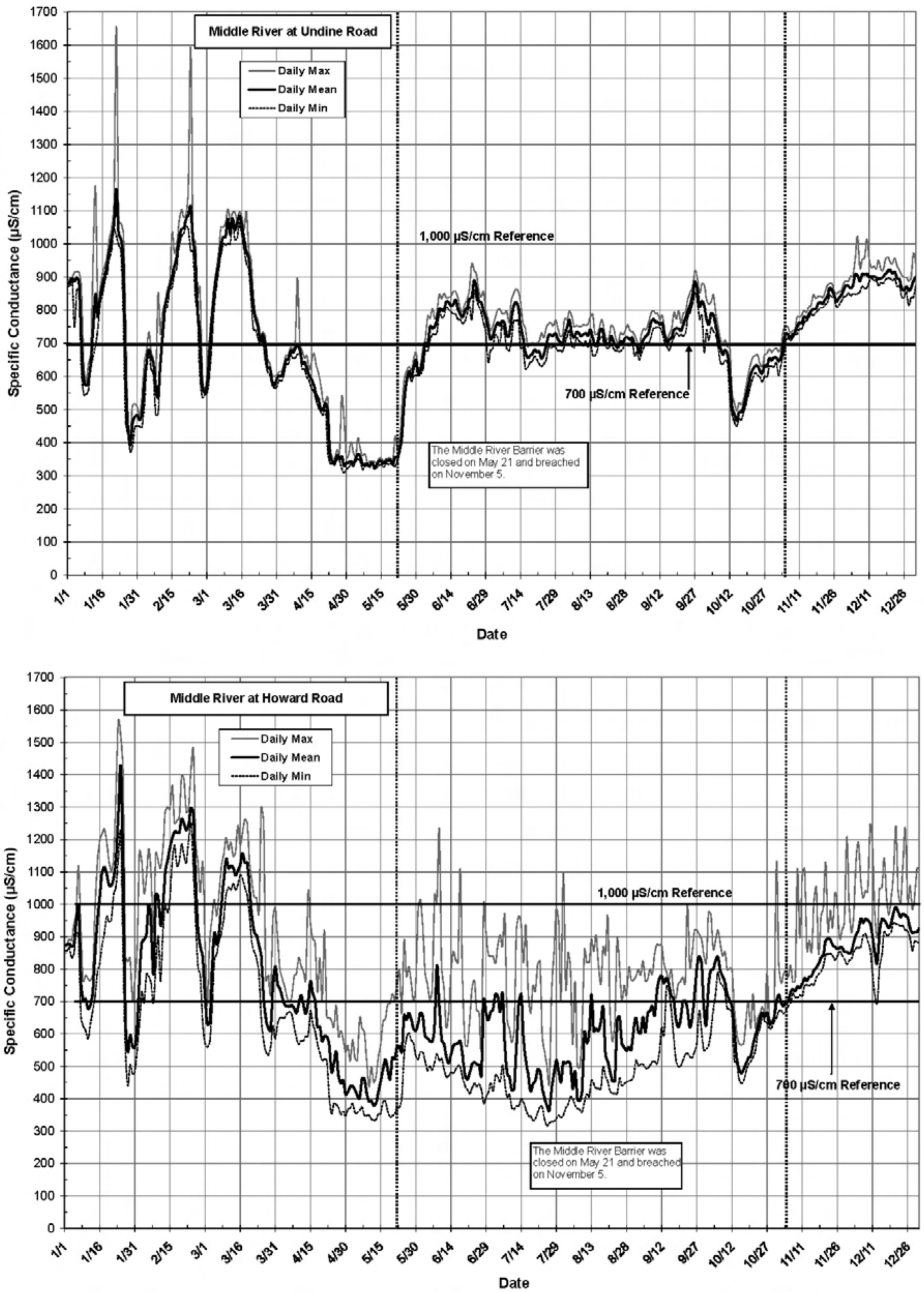
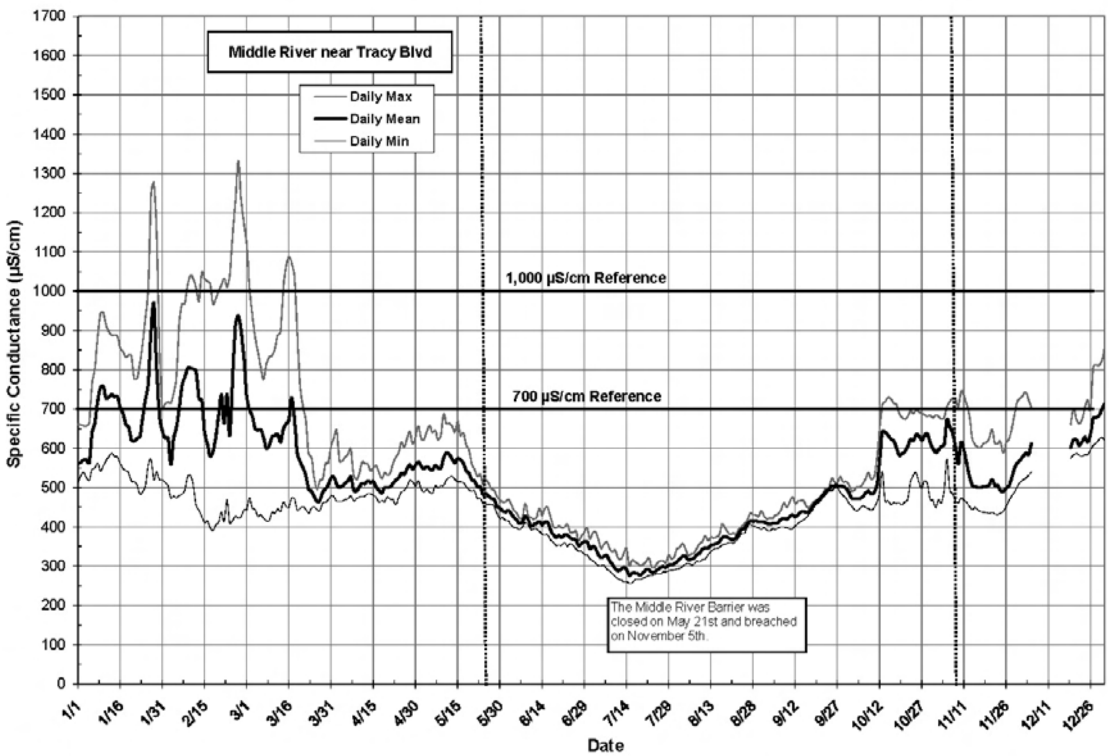


Figure 6-32. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) specific conductance data



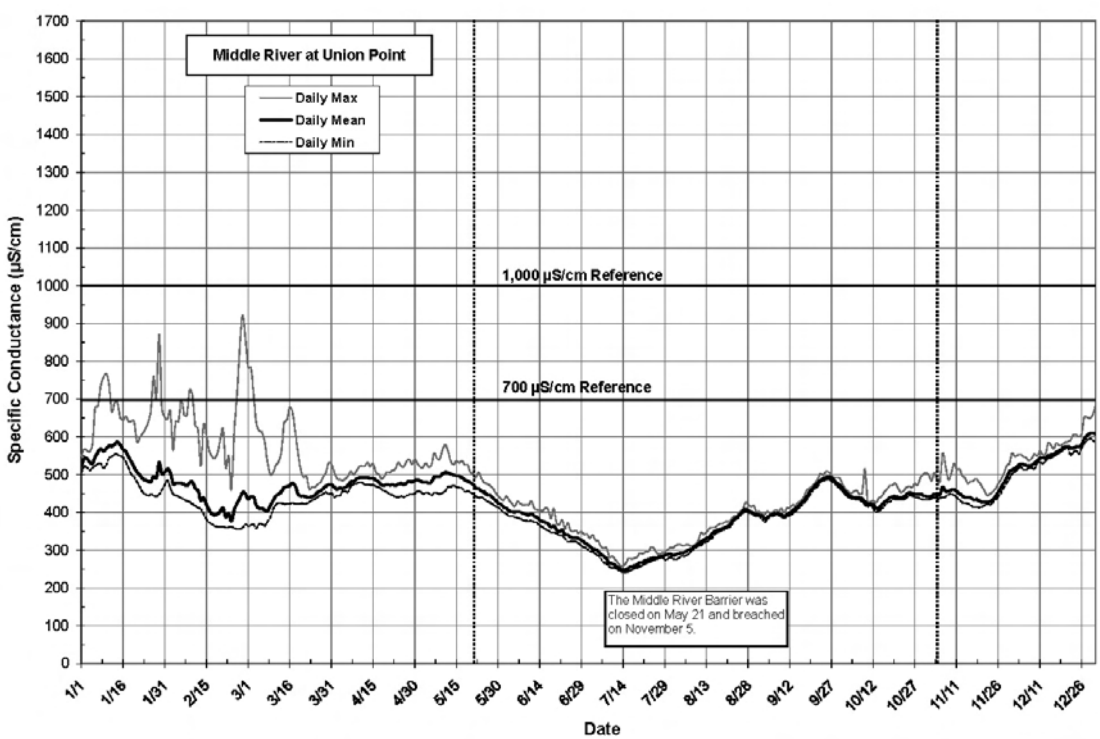
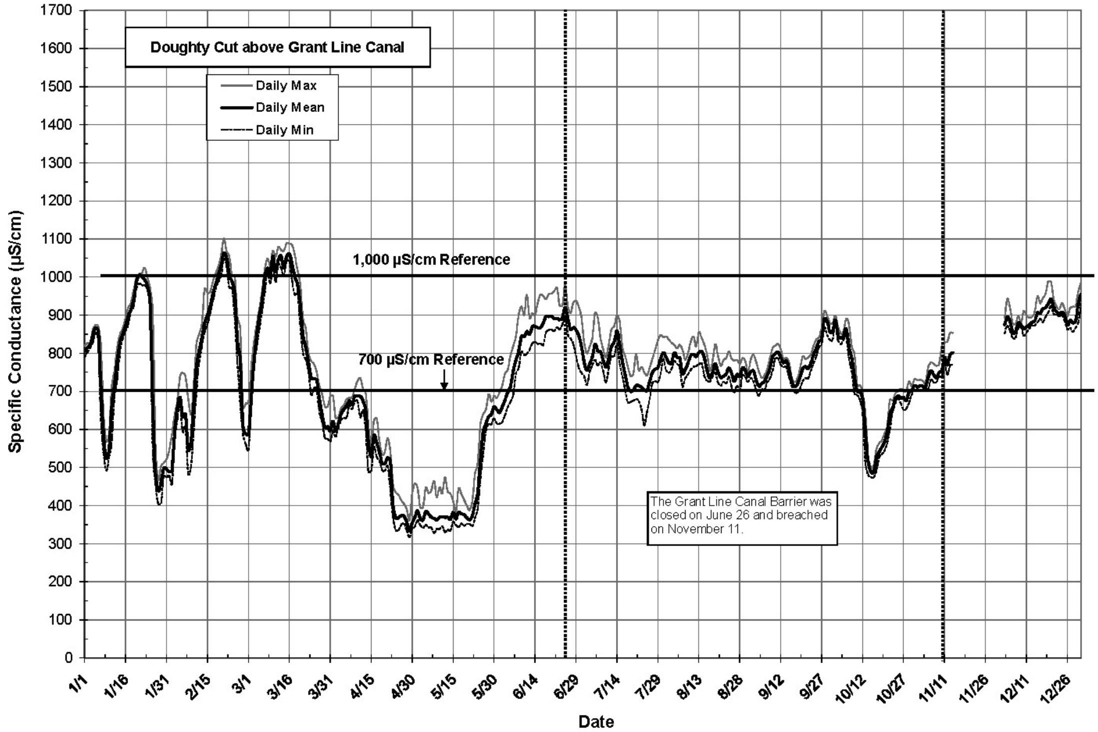


Figure 6-33. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) specific conductance data



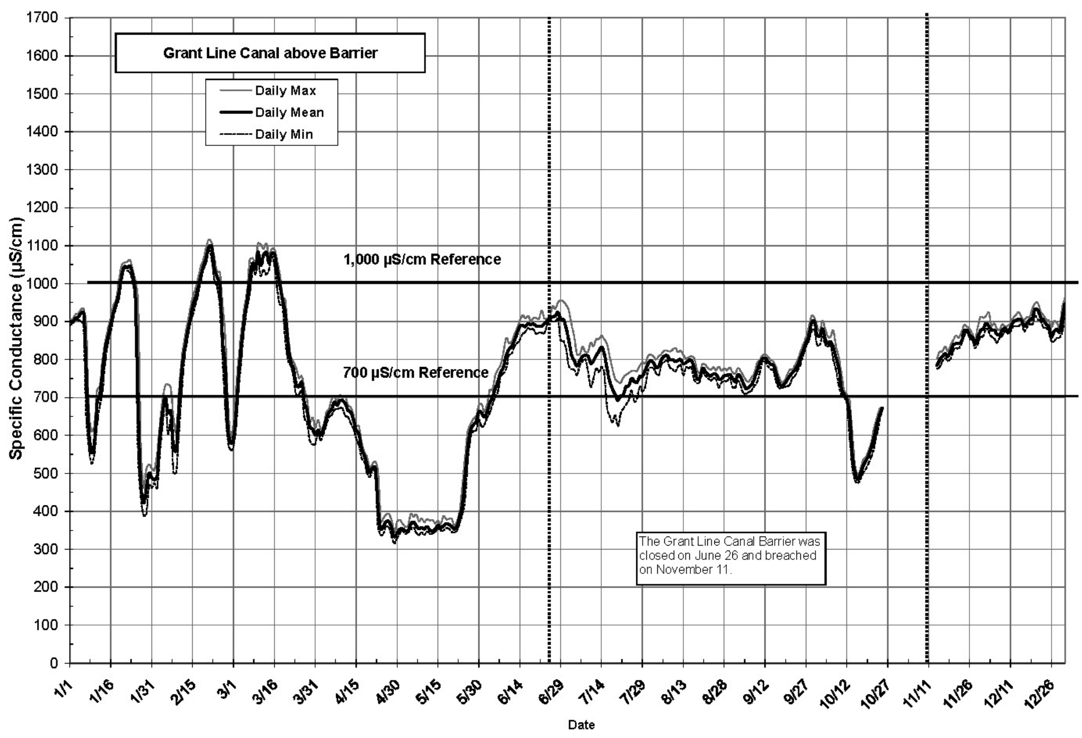


Figure 6-34. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) specific conductance data

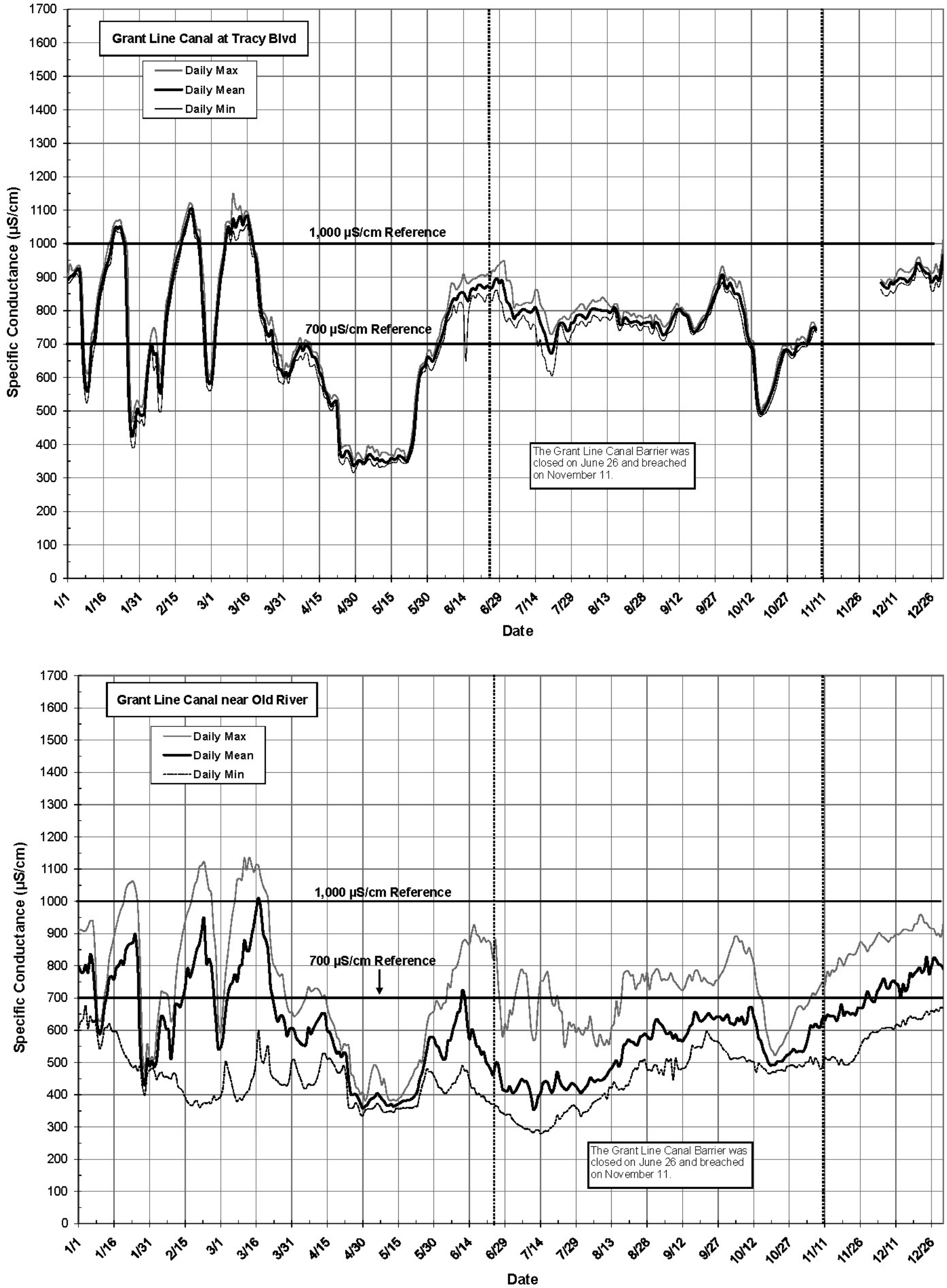


Figure 6-35. Victoria Canal daily (maximum, mean, minimum) specific conductance data

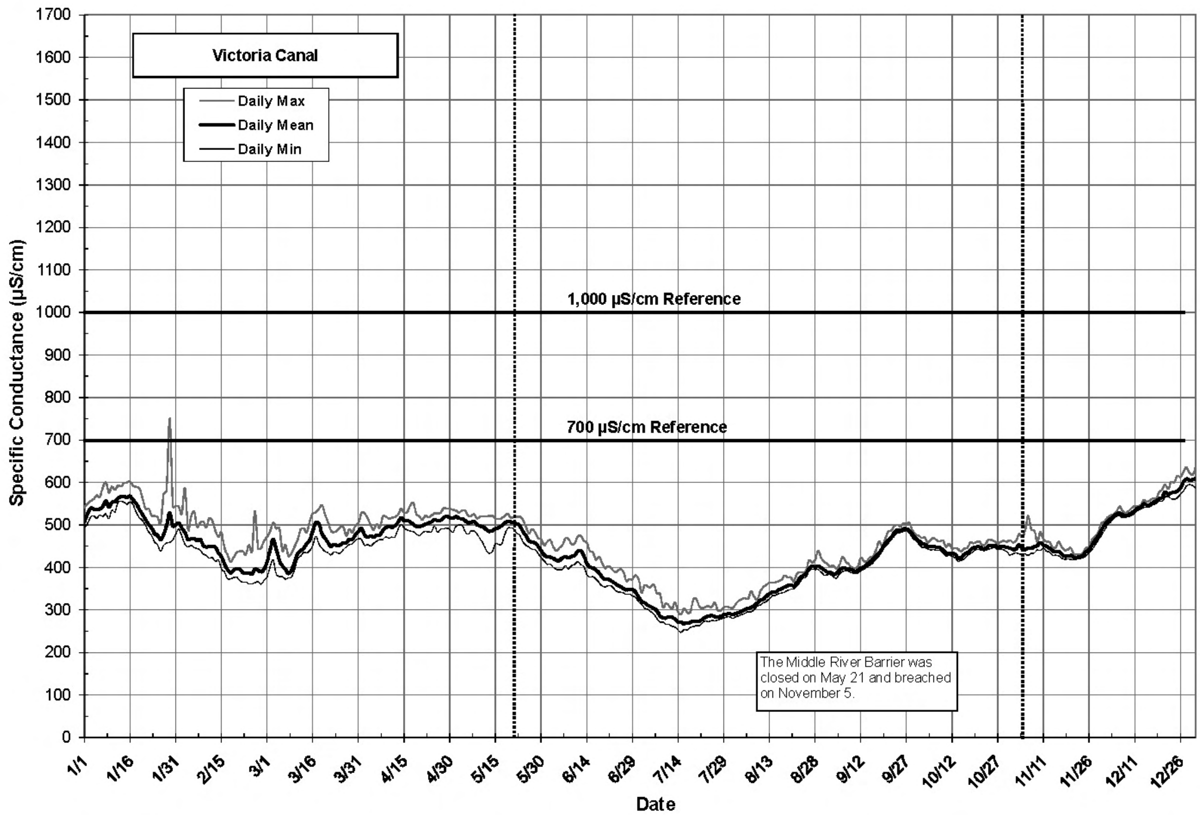


Table 6-6 Statistical summary of 2008 GLC continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Maximums	Doughty Cut	GLC abv Bar	Tracy Blvd	GLC n OR
January	10.88	10.61	10.87	10.94
February	14.66	14.57	14.57	14.10
March	17.04	17.07	17.03	16.96
April	20.15	19.99	20.01	19.47
May	24.37	24.15	24.01	23.94
June	27.36	27.11	26.97	26.72
July	28.97	29.34	28.04	28.82
August	29.16	28.52	27.60	26.66
September	27.90	26.30	26.23	25.81
October	25.38	25.00	22.63	23.79
November	17.54	16.53	17.56	17.49
December	12.42	13.16	11.99	13.32
Averages	**Doughty Cut**	**GLC abv Bar**	**Tracy Blvd**	**GLC n OR**
January	8.83	8.82	8.98	8.63
February	11.16	11.21	11.23	10.79
March	14.97	15.05	15.01	14.85
April	16.60	16.51	16.45	16.44
May	19.40	19.37	19.35	19.44
June	23.24	23.18	23.15	22.75
July	25.30	25.25	24.76	24.75
August	25.26	24.86	24.90	24.71
September	23.46	23.34	22.88	22.98
October	18.41	18.53	17.39	18.38
November	15.22	14.27	15.51	15.07
December	9.05	9.49	8.98	9.35

Month	Dissolved oxygen (mg/L)			
Maximums	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	11.64	11.99	12.14	11.48
February	13.54	11.74	11.47	11.01
March	15.17	14.07	14.68	12.56
April	17.52	16.56	17.54	14.71
May	17.79	16.17	17.68	11.56
June	14.70	14.00	13.44	10.02
July	15.86	15.13	11.39	12.85
August	13.56	13.11	9.86	8.12
September	17.90	18.57	16.48	8.91
October	15.47	15.16	15.57	10.18
November	14.17	13.77	12.30	13.65
December	12.87	12.25	11.69	12.03
Averages	**Doughty Cut**	**GLC abv Bar**	**Tracy Blvd**	**GLC n OR**
January	10.25	10.82	10.40	9.77
February	10.89	10.10	10.03	9.76
March	11.89	11.61	11.56	10.03
April	12.56	12.60	12.76	10.63
May	10.63	10.23	10.36	8.07
June	8.20	7.15	6.06	5.98
July	6.25	5.21	4.79	6.62
August	6.54	5.03	4.72	6.81
September	9.96	7.72	7.81	7.27
October	10.44	8.98	9.88	8.60
November	10.67	10.81	8.83	9.77
December	11.68	11.13	10.69	10.65

Month	pH			
Maximums	Doughty Cut	GLC abv Bar	Tracy Blvd	GLC n OR
January	8.18	8.07	8.15	7.89
February	8.27	7.92	8.10	8.03
March	8.82	8.85	8.69	8.65
April	9.07	9.22	9.12	9.03
May	9.13	9.10	9.04	8.51
June	9.17	9.29	9.20	8.99
July	9.13	9.23	8.96	8.76
August	8.86	8.81	8.56	7.59
September	8.94	9.19	8.76	7.88
October	8.91	8.89	8.67	7.97
November	8.60	8.56	8.28	8.15
December	8.48	8.32	7.97	8.00
Averages	**Doughty Cut**	**GLC abv Bar**	**Tracy Blvd**	**GLC n OR**
January	7.78	7.85	7.84	7.58
February	7.85	7.64	7.86	7.75
March	8.33	8.21	8.29	7.93
April	8.48	8.50	8.61	8.38
May	8.01	7.97	8.05	7.40
June	8.29	8.07	8.03	7.58
July	8.28	8.08	8.06	7.50
August	8.20	7.89	7.76	7.22
September	8.24	8.06	8.01	7.57
October	8.13	7.92	7.79	7.58
November	8.05	7.94	7.74	7.66
December	8.30	8.09	7.62	7.62

Table 6-6 (cont.). Statistical summary of 2008 GLC continuous water temperature, dissolved oxygen, and pH data

Month	Water Temperature (°C)			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	7.41	7.55	7.44	7.15
February	8.39	8.41	8.56	8.11
March	12.75	13.16	13.17	12.42
April	14.30	14.39	14.33	14.47
May	16.31	16.39	16.38	16.46
June	19.18	19.03	19.15	19.00
July	22.54	22.98	22.58	22.74
August	22.87	22.33	22.84	22.84
September	20.72	20.86	19.56	20.64
October	13.70	14.32	12.46	15.65
November	13.25	12.60	12.65	12.62
December	6.71	7.01	7.04	6.65
Std. devs.	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	0.64	0.66	0.73	0.75
February	1.49	1.51	1.51	1.46
March	0.96	0.86	0.86	0.96
April	1.30	1.30	1.28	1.13
May	1.85	1.85	1.83	1.79
June	1.90	1.93	1.83	1.86
July	1.39	1.35	1.11	0.94
August	1.17	1.12	0.95	0.67
September	1.43	1.20	1.58	1.16
October	2.61	2.87	2.41	2.16
November	1.04	1.21	1.73	1.09
December	1.34	1.64	1.21	1.98
2008–Max.	29.16	29.34	28.04	28.82
2008–Avg.	17.83	17.61	17.63	17.36
2008–Min.	6.71	7.01	7.04	6.65
2008–S.D.	6.00	5.98	5.84	5.74

Month	Dissolved oxygen (mg/L)			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	8.06	9.05	9.17	8.17
February	8.08	8.19	8.73	8.35
March	8.48	8.64	8.73	7.81
April	9.66	10.20	10.03	7.95
May	8.89	7.87	7.60	4.35
June	1.20	0.82	0.89	1.08
July	1.05	0.56	1.05	3.91
August	2.54	1.34	1.49	4.34
September	2.55	2.40	4.33	4.49
October	7.15	4.73	6.50	5.19
November	7.41	8.44	6.87	6.49
December	9.68	9.37	9.45	8.88
Std. devs.	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	0.61	0.72	0.78	0.74
February	1.10	0.63	0.52	0.53
March	1.28	1.12	1.12	1.04
April	1.31	1.15	1.36	1.28
May	1.18	1.18	1.27	1.12
June	3.13	3.38	2.70	1.69
July	2.57	2.53	1.72	0.86
August	1.94	1.72	1.34	0.66
September	2.50	2.22	2.00	0.94
October	1.34	1.48	1.64	0.97
November	1.74	0.89	1.47	1.22
December	0.81	0.79	0.51	0.57
2008 - Max.	17.90	18.57	17.68	14.71
2008 - Avg.	9.93	9.22	8.98	8.66
2008 - Min.	1.05	0.56	0.89	1.08
2008 - S.D.	2.66	2.98	3.00	1.89

Month	pH			
Minimums	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	7.35	7.66	7.61	7.29
February	7.28	7.17	7.65	7.21
March	7.83	7.59	7.79	7.28
April	7.83	7.75	8.06	7.79
May	7.45	7.46	7.46	6.74
June	7.40	7.27	7.32	7.24
July	7.63	7.46	7.38	7.25
August	7.74	7.55	7.49	6.98
September	7.62	7.51	7.63	6.98
October	7.56	7.40	7.23	7.27
November	7.71	7.59	7.44	7.17
December	8.04	7.68	7.23	7.20
Std. devs.	Doughty Cut	GLC abv Bar.	Tracy Blvd	GLC n OR
January	0.18	0.12	0.16	0.13
February	0.22	0.15	0.12	0.16
March	0.21	0.30	0.21	0.36
April	0.25	0.28	0.25	0.34
May	0.34	0.34	0.31	0.34
June	0.42	0.56	0.54	0.36
July	0.32	0.39	0.34	0.17
August	0.21	0.24	0.19	0.14
September	0.25	0.28	0.22	0.21
October	0.28	0.25	0.25	0.15
November	0.22	0.19	0.17	0.21
December	0.07	0.12	0.16	0.25
2008 - Max.	9.17	9.29	9.20	9.03
2008 - Avg.	8.14	7.98	7.91	7.65
2008 - Min.	7.28	7.17	7.23	6.74
2008 - S.D.	0.34	0.38	0.39	0.37

Table 6-7. Statistical summary of 2008 Old River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (µS/cm)			
Maximums	**Near head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	1172.5	1187.2	1198.8
February	-	1271.6	1271.8	1276.9
March	975.9	1363.9	1336.6	1341.8
April	714.6	950.8	949.7	900.8
May	664.3	783.7	741.3	727.5
June	916.0	1215.9	1032.9	1031.0
July	830.2	1040.5	1072.2	1080.7
August	770.6	974.5	1013.5	1011.5
September	913.1	998.4	1048.0	1035.8
October	854.5	983.2	1015.7	1019.7
November	896.6	1066.5	1144.7	1162.7
December	972.8	1356.6	1278.2	1259.0
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	907.0	802.4	800.3
February	-	894.4	762.6	749.3
March	710.6	960.5	829.5	797.3
April	519.6	676.1	605.4	593.6
May	404.1	510.1	467.1	460.1
June	779.9	957.3	618.1	601.5
July	667.0	821.7	603.5	561.7
August	691.4	840.8	721.8	687.3
September	749.9	848.6	868.5	835.5
October	643.4	813.4	802.9	784.8
November	779.8	914.9	760.8	745.6
December	888.1	1083.8	846.2	837.1

Month	Turbidity (NTU)			
Maximums	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	121.2	149.1	154.2
February	-	88.8	222.9	60.5
March	50.4	51.0	119.7	70.0
April	65.1	44.9	163.8	72.4
May	81.4	69.8	98.0	72.8
June	92.1	154.0	46.3	62.9
July	87.7	116.3	62.1	49.2
August	47.6	66.4	62.5	49.0
September	80.5	69.8	44.1	29.1
October	45.7	29.6	27.3	34.7
November	39.7	44.6	128.7	120.7
December	69.4	45.9	52.1	29.7
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	36.6	26.0	27.7
February	-	33.4	29.0	30.3
March	18.8	25.7	25.3	26.8
April	18.6	30.4	34.9	30.4
May	22.8	25.0	27.8	30.2
June	33.0	39.9	18.7	22.1
July	29.9	42.7	20.2	17.5
August	21.2	21.2	17.1	15.5
September	14.2	18.1	11.3	12.5
October	8.8	17.0	12.3	13.6
November	8.0	16.9	13.8	16.4
December	9.4	12.9	8.7	9.1

Month	Chlorophyll *a* (µg/L)			
Maximums	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	45.2	30.5	29.1
February	-	60.2	57.7	24.4
March	45.3	255.8	329.1	556.8
April	110.9	341.1	203.7	311.0
May	214.7	175.2	29.2	43.2
June	445.0	186.1	52.2	78.4
July	304.7	406.4	175.2	136.3
August	224.5	103.2	102.8	132.6
September	216.1	299.2	9.8	27.1
October	162.8	112.7	34.5	33.3
November	115.5	165.4	43.0	74.5
December	116.3	298.7	51.6	41.2
Averages	**Near Head**	**Tracy Wildlife Association**	**Above ORT barrier**	**Below ORT barrier**
January	-	17.0	6.0	7.2
February	-	24.3	14.6	7.4
March	28.8	80.8	45.0	57.2
April	54.9	183.8	52.3	59.5
May	54.8	62.8	5.9	6.0
June	228.3	64.0	6.1	6.3
July	162.3	139.6	13.2	8.7
August	84.4	35.3	11.3	7.9
September	77.8	37.6	3.4	5.2
October	41.1	30.5	7.0	6.0
November	30.0	39.5	8.0	10.6
December	21.4	49.6	4.7	5.5

Table 6-7 (cont.). Statistical summary of 2008 Old River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (µS/cm)			
Minimums	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	465.9	417.8	420.3
February	-	504.3	348.6	354.4
March	556.5	618.6	368.9	375.2
April	298.9	384.8	354.1	362.1
May	311.3	386.1	308.4	359.0
June	620.4	681.8	342.6	341.3
July	539.4	674.8	283.6	285.6
August	579.3	759.3	384.2	359.5
September	644.3	744.3	545.6	512.8
October	443.6	530.7	420.9	481.8
November	634.1	701.7	488.3	492.9
December	837.6	955.1	607.4	605.6
Std. devs.	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	189.0	201.6	202.2
February	-	192.5	268.4	267.6
March	115.2	189.8	274.7	250.8
April	134.3	134.4	149.1	135.8
May	117.2	93.3	81.0	77.9
June	55.8	113.3	142.9	147.6
July	51.3	61.3	211.8	209.2
August	29.2	33.6	177.5	177.7
September	53.2	46.9	133.2	148.9
October	100.4	108.6	134.9	146.3
November	62.7	91.0	191.3	190.3
December	28.1	82.0	186.3	182.3
2008—Max.	975.9	1363.9	1336.7	1341.0
2008—Avg.	681.4	852.2	724.0	704.0
2008—Min.	298.9	384.8	283.6	285.6
2008—S.D.	157.6	186.9	221.5	219.1

Month	Turbidity (NTU)			
Minimums	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	4.7	1.8	4.3
February	-	16.4	10.2	11.0
March	11.4	15.6	8.3	8.1
April	8.4	19.2	10.2	8.7
May	11.9	11.4	12.6	12.4
June	17.8	19.7	7.7	7.2
July	16.3	20.6	8.4	6.5
August	5.6	12.0	6.8	5.2
September	5.7	8.2	2.8	3.9
October	4.9	9.0	3.1	2.8
November	3.9	7.8	2.9	2.3
December	3.5	5.5	2.5	1.8
Std. devs.	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	26.4	18.3	19.5
February	-	12.9	11.5	10.1
March	4.4	4.9	10.7	9.1
April	6.9	4.5	14.6	10.6
May	6.4	6.3	9.0	9.1
June	7.5	13.8	5.1	7.1
July	6.8	11.0	6.9	5.3
August	5.6	5.1	6.3	5.3
September	7.2	6.2	5.0	4.5
October	2.8	2.9	4.7	5.3
November	1.2	1.2	9.8	12.1
December	6.1	3.5	4.6	4.8
2008—Max.	92.1	154.0	222.9	154.2
2008—Avg.	18.3	26.6	20.3	20.9
2008—Min.	3.5	4.7	1.8	1.8
2008—S.D.	10.3	14.4	12.5	12.1

Month	Chlorophyll *a* (µg/L)			
Minimums	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	6.1	0.3	0.6
February	-	8.4	3.9	2.1
March	16.3	15.1	4.0	4.5
April	16.1	72.0	5.8	2.6
May	12.7	16.8	1.8	1.1
June	63.7	5.1	1.6	1.2
July	30.8	20.3	2.1	1.0
August	16.1	10.2	2.3	0.7
September	10.0	7.6	1.2	0.7
October	2.5	8.8	0.4	0.6
November	5.4	5.6	0.4	1.2
December	5.4	9.2	0.8	1.2
Std. devs.	**Near Head**	**Tracy Wildlife Assoc.**	**Above ORT barrier**	**Below ORT barrier**
January	-	5.8	5.8	0.6
February	-	10.6	6.5	2.1
March	5.9	40.9	57.4	4.5
April	21.9	62.2	41.8	2.6
May	38.3	26.7	3.0	1.1
June	83.7	52.2	5.6	1.2
July	55.8	63.5	17.6	1.0
August	33.7	14.4	15.5	0.7
September	40.2	29.3	0.9	0.7
October	34.4	11.3	6.4	0.6
November	17.7	23.1	6.0	1.2
December	15.9	31.9	4.1	1.2
2008—Max.	445.0	406.4	329.1	556.8
2008—Avg.	81.1	63.7	14.7	15.6
2008—Min.	2.5	5.1	0.3	0.6
2008—S.D.	76.2	60.0	26.9	36.5

Table 6-8. Statistical summary of 2008 Middle River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (µS/cm)			
Maximums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	1656.2	1563.9	1275.0	870.8
February	1592.6	1476.3	1332.3	920.2
March	1104.9	1298.0	1114.9	784.9
April	897.1	1039.7	644.9	540.3
May	670.7	988.7	687.1	578.9
June	940.2	1231.4	469.2	443.1
July	863.2	985.6	386.9	342.8
August	796.6	1097.7	440.0	425.8
September	919.0	1000.5	527.5	508.1
October	875.8	1130.6	729.5	514.3
November	881.0	1207.2	744.9	557.1
December	1022.7	1244.1	853.0	680.6
Averages	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	787.2	895.0	690.0	534.4
February	791.3	1045.5	719.0	440.7
March	852.7	917.3	594.5	445.1
April	535.4	627.8	515.3	477.9
May	405.3	498.2	529.0	475.1
June	785.3	573.9	395.8	370.8
July	721.7	527.0	301.5	275.7
August	718.0	547.1	362.2	345.8
September	756.4	696.3	450.4	432.2
October	635.0	652.0	567.9	437.7
November	778.9	794.3	549.8	449.1
December	892.5	926.8	630.3	556.7

Month	Turbidity (NTU)			
Maximums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	191.8	69.3	65.3	40.6
February	176.5	49.6	54.6	38.2
March	101.0	32.3	28.5	23.3
April	91.3	49.3	56.4	21.9
May	109.4	143.0	44.4	24.8
June	146.1	139.1	76.4	25.0
July	119.8	120.0	59.1	33.2
August	98.4	82.5	32.0	19.4
September	132.8	119.0	29.3	15.7
October	77.3	79.1	40.4	29.3
November	60.7	40.1	46.9	18.1
December	23.1	8.4	23.5	8.7
Averages	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	41.4	15.5	14.7	11.6
February	27.4	9.8	17.3	18.1
March	20.2	6.5	11.4	10.9
April	22.9	11.4	12.6	7.6
May	29.6	12.5	13.8	7.0
June	56.9	14.5	14.7	8.5
July	41.9	18.8	13.0	8.6
August	20.2	15.4	9.3	6.0
September	24.6	13.6	7.6	4.2
October	13.5	7.6	6.9	3.4
November	6.3	1.9	6.5	2.8
December	6.4	1.1	4.6	2.6

Month	Chlorophyll *a* (µg/L)			
Maximums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	48.9	21.4	13.3	5.4
February	60.7	12.0	8.3	6.9
March	332.6	38.3	9.1	5.9
April	204.0	102.4	13.1	7.6
May	245.6	17.4	24.6	6.7
June	709.9	58.5	20.3	5.5
July	431.1	85.1	6.9	5.1
August	386.3	26.8	10.1	7.1
September	411.6	30.4	7.9	6.0
October	149.2	15.4	11.8	4.5
November	149.2	12.0	10.4	5.4
December	46.3	17.9	10.4	6.4
Averages	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	11.4	4.5	3.6	4.1
February	14.0	3.3	5.1	4.5
March	67.2	3.7	4.5	4.3
April	73.9	6.1	5.7	3.5
May	49.8	3.8	5.9	4.4
June	294.8	7.9	4.4	4.2
July	201.1	7.9	3.4	2.9
August	82.9	5.3	3.3	2.8
September	81.3	4.6	2.3	2.8
October	49.4	3.7	3.5	3.1
November	33.6	2.0	2.3	2.7
December	7.9	1.6	2.4	3.2

Table 6-8 (cont.). Statistical summary of 2008 Middle River continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (µS/cm)			
Minimums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	373.3	440.3	483.3	441.9
February	445.2	553.5	390.7	355.2
March	549.6	535.3	415.5	357.7
April	310.0	347.2	456.5	440.4
May	318.7	333.1	421.6	406.9
June	607.6	385.2	328.6	307.7
July	622.9	316.8	256.6	241.6
August	662.0	348.7	293.2	275.4
September	649.9	494.3	389.7	374.9
October	450.6	446.8	441.1	402.1
November	603.5	662.3	431.7	413.7
December	815.2	693.5	509.9	501.5
Std. devs.	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	215.5	229.7	140.7	53.1
February	205.8	193.3	206.1	76.4
March	178.0	191.7	146.6	51.0
April	127.3	116.6	33.6	18.3
May	110.0	114.9	53.4	30.2
June	59.4	128.4	28.5	30.4
July	49.8	173.9	24.4	19.7
August	23.0	141.7	34.7	40.5
September	53.2	112.9	37.1	40.4
October	95.9	113.5	82.5	14.6
November	63.6	72.5	82.4	23.3
December	26.4	56.0	66.3	30.2
2008—Max.	1656.2	1563.9	1332.3	920.2
2008—Avg.	721.3	724.1	520.8	436.8
2008—Min.	310.0	316.8	256.6	241.6
2008—S.D.	177.8	228.6	156.5	84.3

Month	Turbidity (NTU)			
Minimums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	3.6	1.4	2.8	2.6
February	3.8	1.7	7.9	10.4
March	6.7	1.2	1.0	4.5
April	6.1	2.8	5.3	3.2
May	7.1	2.2	3.6	3.3
June	21.9	1.5	7.2	4.8
July	19.4	2.0	7.0	4.0
August	2.1	1.6	2.8	2.8
September	6.1	1.0	1.2	1.6
October	3.5	0.9	2.5	0.2
November	1.9	0.6	2.1	0.1
December	2.6	0.0	1.2	1.1
Std. devs.	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	40.2	13.4	9.1	4.7
February	19.5	6.9	4.3	2.7
March	10.9	5.4	3.8	2.9
April	13.7	5.3	5.5	2.2
May	16.5	13.8	5.8	1.7
June	18.8	13.6	7.0	2.0
July	15.2	13.5	5.2	2.3
August	10.1	10.6	4.1	1.7
September	11.2	10.8	4.0	1.4
October	7.8	9.8	3.2	2.2
November	4.1	1.6	3.0	1.7
December	2.3	0.8	2.1	0.9
2008—Max.	191.8	143.0	76.4	40.6
2008—Avg.	25.9	10.6	10.9	7.6
2008—Min.	1.9	0.0	1.0	0.1
2008—S.D.	22.3	11.4	6.4	4.8

Month	Chlorophyll *a* (µg/L)			
Minimums	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	1.1	0.4	1.5	2.8
February	1.6	0.5	2.4	3.5
March	7.3	0.5	1.6	3.3
April	11.6	0.5	3.4	1.8
May	3.5	0.4	2.4	3.0
June	77.8	1.9	1.8	3.0
July	30.6	1.5	1.3	1.8
August	20.3	1.9	1.7	1.1
September	5.1	0.6	0.5	1.4
October	10.4	0.6	1.1	1.7
November	5.6	0.5	0.3	1.7
December	1.60	0.1	0.9	2.0
Std. devs.	**Undine Road**	**Howard Road**	**Near Tracy Boulevard**	**Union Point**
January	9.0	3.3	1.1	0.3
February	10.8	1.7	0.9	0.3
March	45.2	3.2	1.1	0.4
April	36.0	7.6	1.0	0.7
May	46.2	2.2	2.0	0.4
June	115.9	4.3	1.6	0.4
July	78.6	8.8	1.1	0.4
August	36.3	2.1	0.7	0.7
September	72.2	2.8	0.7	0.5
October	34.7	2.0	1.0	0.3
November	22.9	0.6	0.8	0.3
December	7.1	1.0	0.6	0.4
2008—Max.	709.9	102.4	24.6	7.6
2008—Avg.	80.5	4.4	3.9	3.5
2008—Min.	1.1	0.1	0.3	1.1
2008—S.D.	97.0	4.3	1.6	0.8

Table 6-9. Statistical summary of 2008 Grant Line Canal continuous specific conductance, turbidity, and chlorophyll *a* data

Month	Specific conductance (μS/cm)			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	1024.4	1062.1	1070.4	1061.8
February	1101.5	1116.3	1122.0	1120.9
March	1088.6	1106.4	1148.6	1135.8
April	733.8	705.5	717.8	733.7
May	692.2	681.8	682.3	690.8
June	978.5	955.6	945.8	926.5
July	906.4	942.6	947.1	788.8
August	854.7	830.2	839.4	782.7
September	910.8	914.1	932.0	800.3
October	899.6	901.6	908.9	889.8
November	861.1	911.8	763.8	872.9
December	987.8	962.5	1014.9	955.9
			-	
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	767.0	797.7	800.5	728.2
February	791.0	810.4	811.9	695.5
March	863.1	872.4	872.5	757.5
April	542.4	549.3	554.0	536.7
May	426.7	417.2	415.4	419.2
June	832.4	838.8	823.0	544.7
July	766.4	774.9	769.4	420.2
August	765.2	777.9	782.1	509.7
September	774.6	778.7	783.7	615.9
October	685.0	684.3	686.1	569.0
November	744.2	839.9	718.4	636.2
December	895.6	892.6	900.6	760.6

Month	Turbidity (NTU)			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	257.0	266.4	217.4	215.6
February	233.3	125.2	100.0	98.8
March	111.9	56.1	50.9	122.0
April	74.4	107.4	75.3	54.0
May	53.8	54.5	49.0	44.1
June	89.8	86.4	105.4	67.3
July	82.9	75.5	163.3	37.0
August	72.6	56.3	42.1	49.9
September	65.1	26.3	56.8	32.4
October	50.1	47.9	34.5	33.7
November	46.5	88.3	77.8	47.0
December	25.3	50.5	30.1	22.9
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	50.9	46.0	46.6	34.7
February	34.8	33.3	34.5	27.4
March	22.2	19.2	19.9	21.8
April	22.5	20.7	20.8	22.2
May	22.0	19.8	20.8	23.6
June	35.2	34.0	36.0	25.2
July	31.7	26.1	30.1	17.7
August	21.5	18.9	18.5	12.4
September	15.9	23.3	15.4	10.7
October	12.7	12.5	12.2	8.5
November	10.1	13.8	16.6	9.3
December	7.9	10.1	10.5	7.6

Month	Chlorophyll *a* (μg/L)			
Maximums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	60.5	39.5	32.9	21.1
February	88.1	69.6	47.2	22.6
March	101.3	126.0	120.6	97.7
April	193.4	161.9	183.6	117.3
May	205.9	131.3	185.3	105.9
June	424.9	214.0	293.7	147.2
July	148.0	268.0	170.2	48.1
August	155.9	77.6	49.7	15.6
September	96.6	181.8	89.1	29.7
October	88.9	46.2	91.9	50.5
November	48.5	91.1	100.7	61.5
December	26.2	64.2	29.3	17.0
Averages	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	18.3	15.2	13.1	5.8
February	21.0	31.4	23.0	9.2
March	51.7	50.4	60.8	30.3
April	102.4	85.7	85.0	37.5
May	46.0	47.6	42.7	13.9
June	146.6	80.1	97.2	13.7
July	67.4	80.9	64.6	3.9
August	21.2	18.1	15.3	4.1
September	30.5	32.5	24.1	3.0
October	33.9	11.8	23.2	5.1
November	21.7	27.2	31.9	6.3
December	11.5	17.5	10.5	3.5

Table 6-9 (cont.). Statistical summary of 2008 Grant Line Canal continuous specific conductance, turbidity, and chlorophyll a data

Month	Specific conductance (µS/cm)			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	403.6	389.5	389.9	399.0
February	456.9	461.6	456.8	360.5
March	545.4	568.4	566.1	379.0
April	316.7	315.4	315.6	333.7
May	328.0	337.4	330.9	344.4
June	614.8	628.5	623.7	336.7
July	610.6	624.8	605.5	278.9
August	697.0	726.2	732.2	343.3
September	688.7	709.8	710.6	445.9
October	473.6	475.0	483.1	465.0
November	701.3	775.3	682.9	480.2
December	839.6	843.5	844.3	593.1
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	182.5	199.3	198.9	185.9
February	184.1	197.5	198.9	230.3
March	165.6	172.1	171.9	222.2
April	121.6	126.2	124.5	107.1
May	88.6	108.6	108.6	78.4
June	81.8	83.6	72.8	156.6
July	48.9	50.6	47.3	120.1
August	27.4	22.0	19.7	97.4
September	48.8	47.0	46.7	83.0
October	116.2	137.5	124.4	104.9
November	30.6	27.3	22.4	120.0
December	27.3	21.4	25.4	118.1
2008—Max.	1101.5	1116.3	1148.6	1135.8
2008—Avg.	735.6	750.5	742.5	599.1
2008—Min.	316.7	315.4	315.6	333.7
2008—S.D.	172.7	181.9	181.4	184.5

Month	Turbidity (NTU)			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	7.6	4.9	5.6	3.9
February	9.5	11.7	10.9	10.7
March	10.0	9.7	9.5	8.1
April	10.1	12.3	10.0	9.2
May	10.8	10.6	10.8	13.1
June	17.4	16.6	16.3	10.1
July	11.6	9.8	12.2	7.0
August	9.2	4.2	9.0	4.6
September	4.0	20.9	7.5	3.7
October	5.0	4.3	6.8	1.7
November	5.9	6.1	6.4	2.3
December	2.6	5.5	4.7	2.3
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	45.8	44.6	44.8	34.3
February	18.7	17.4	18.7	13.0
March	9.3	6.7	6.3	7.0
April	7.3	6.2	5.9	6.2
May	7.0	5.5	7.0	5.6
June	8.2	7.3	8.2	9.6
July	9.4	8.4	8.7	5.6
August	6.3	5.8	4.2	4.9
September	6.2	1.2	3.7	4.6
October	3.6	3.4	2.8	4.3
November	2.7	5.0	6.6	5.4
December	2.2	2.9	3.7	3.7
2008—Max.	257.0	266.4	217.4	215.6
2008—Avg.	24.9	22.3	23.8	18.4
2008—Min.	2.6	3.2	4.7	1.7
2008—S.D.	20.0	18.2	18.7	14.6

Month	Chlorophyll *a* (µg/L)			
Minimums	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	6.6	2.6	2.3	0.6
February	9.7	14.4	10.9	3.8
March	14.9	13.9	16.2	5.7
April	29.4	21.5	29.0	3.6
May	14.3	18.2	12.9	2.5
June	17.0	5.3	3.1	1.0
July	7.8	7.5	5.2	0.9
August	3.0	2.6	5.0	1.0
September	1.8	2.4	6.5	0.9
October	6.0	1.7	6.5	0.8
November	3.9	2.8	5.2	0.6
December	4.1	6.8	3.2	1.1
Std. devs.	Doughty Cut	Above GLC barrier	Tracy Boulevard	Near Old River
January	8.1	7.5	6.9	4.2
February	6.4	11.2	7.3	3.7
March	17.4	18.6	20.7	19.1
April	36.5	24.2	32.6	27.0
May	42.0	22.9	33.2	12.1
June	75.5	49.5	79.8	23.2
July	37.5	58.1	45.5	4.9
August	14.7	7.7	5.7	1.4
September	20.0	19.4	10.8	1.3
October	16.8	6.5	10.9	3.6
November	10.9	16.2	19.2	7.7
December	3.7	5.6	5.0	1.7
2008—Max.	424.9	268.0	293.7	147.2
2008—Avg.	49.2	41.0	40.8	11.3
2008—Min.	1.8	1.7	2.3	0.6
2008—S.D.	50.3	37.0	41.9	16.5

January–March 2008 and September–December 2008. A maximum of 1,656.2 µS/cm was recorded on January 22 at Middle River at Undine Road. The minimum recorded specific conductance was 355.2 µS/cm on February 26 at Middle River at Union Point. Monthly mean values for this time period ranged from 427.8 µS/cm at Victoria Canal to 1,045.5 µS/cm at Middle River at Howard Road. The lowest monthly mean conductance values were recorded at Middle River near Tracy Boulevard, Middle River at Union Point, and Victoria Canal.

ANOVA Analysis

Old River. ANOVA was performed on average daily specific conductance concentration data to determine whether monthly mean concentrations from April through August differed among 4 Old River monitoring locations (near head, at the Tracy Wildlife Association, upstream of the ORT barrier, and downstream of the ORT barrier). Test results showed that at least 1 mean of these stations was significantly different in each of the following months: April, May, June, July, and August.

April: **($F(3,116)=11$, $p < .01$)**
May: **($F(3,120)=8.6$, $p < .01$)**
June: **($F(3,116)=154$, $p < .01$)**
July: **($F(3,120)=61$, $p < .01$)**
August: **($F(3,120)=28.6$, $p < .01$)**

Explanation of the statistical result $F(3,116)=11$, $p < .001$: $F(3,116)$ refers to the between-groups degrees of freedom (3) and the within-groups degrees of freedom (116). The F-statistic (11) and p-value (< .01) were calculated from the ANOVA test. Statistical significance was based on having a p-value of less than .01.

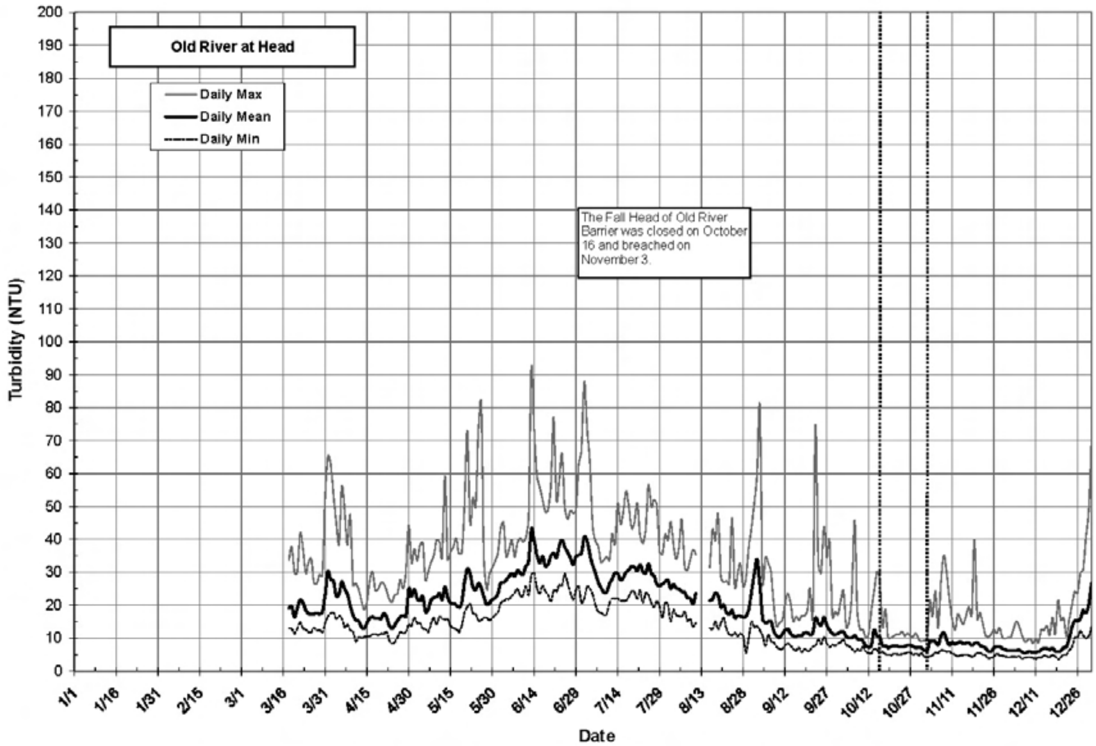
Tukey's HSD test was then performed to determine which mean site conductance values differed. The results showed that specific conductance values were significantly higher ($p < .01$) at Old River at Tracy Wildlife Association in comparison with each of the other 3 sites in June, July, and August. Specific conductance values at Old River at Tracy Wildlife Association were significantly higher ($p < .01$) than at Old River at head in April, May, June, July, and August. There were no significant ($p > .05$) differences in specific conductance values between the sites upstream and downstream of the ORT barrier.

Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, organic and inorganic matter, plankton, and other microscopic organisms (American Public Health Association 2005). Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (American Public Health Association 2005). In surface waters with reduced water clarity, phytoplankton and aquatic plant growth may be adversely affected because of reduced light penetration in the water column.

Turbidity values ranged from a high of 266.4 NTU on January 10 at Grant Line Canal above the GLC barrier to a low of 0.0 NTU on December 20 at Middle River at Howard Road (Figures 6-36 through 6-42 and Tables 6-6 through 6-9). Generally, single high turbidity spikes can be attributed to a foreign object, such as a leaf or fish passing before the optic sensors as the instrument is taking a reading. These anomalies are usually flagged if a single value is greater than 200 NTU; however, there are times during the year when several continuous readings reveal a true event. Summer and winter (January) turbidity readings were the highest, with mean monthly values ranging from 5.8 NTU in August at Victoria Canal to 56.9 NTU in June at Middle River at Undine Road. Fall turbidity readings were the lowest, with Middle River near Tracy Boulevard, Middle River at Union Point, and Victoria Canal being the least turbid sites.

Figure 6-36. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) turbidity data



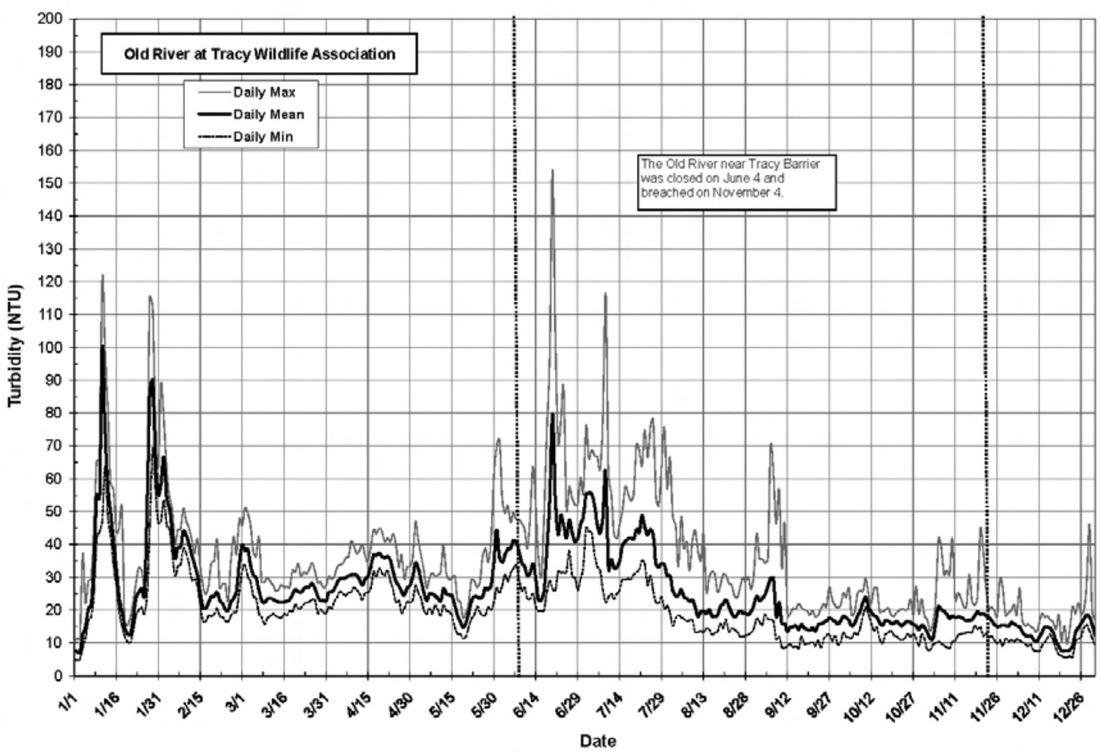
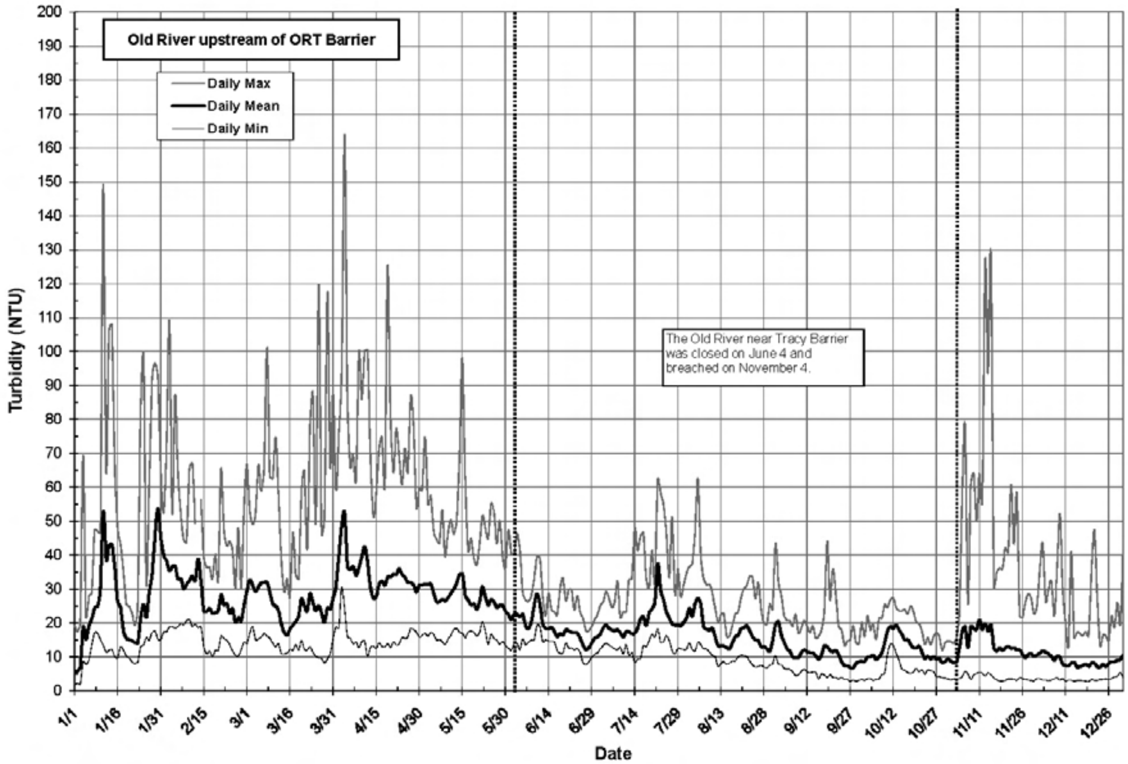


Figure 6-37. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) turbidity data



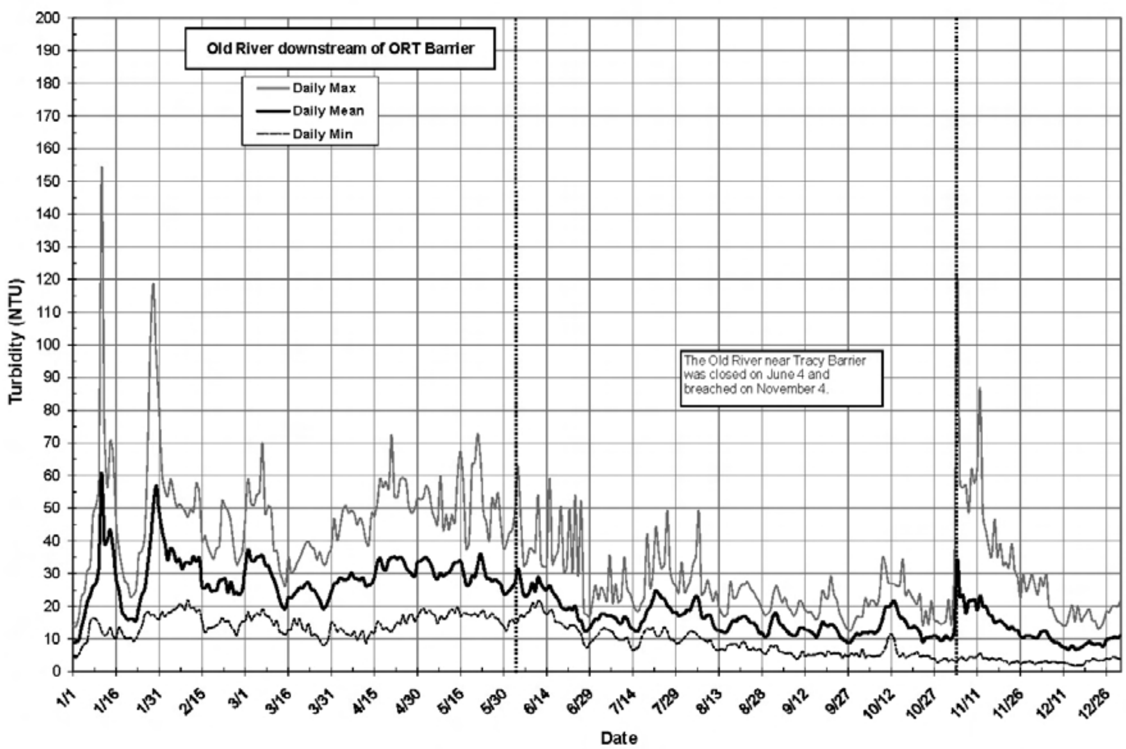
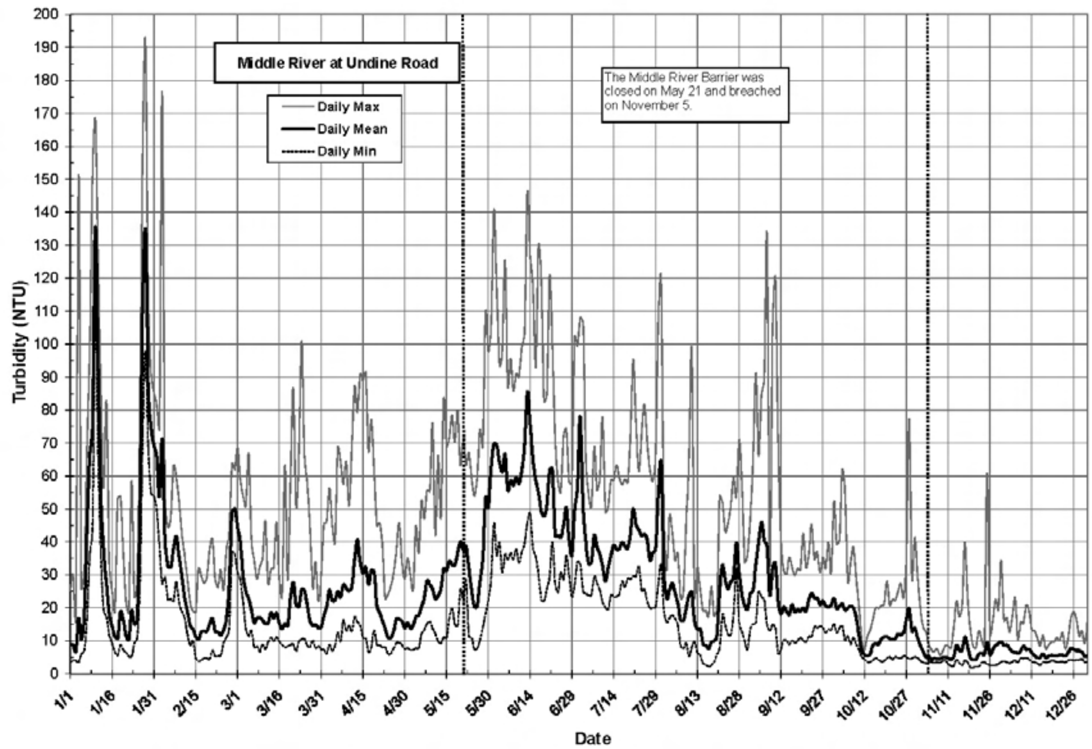


Figure 6-38. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) turbidity data



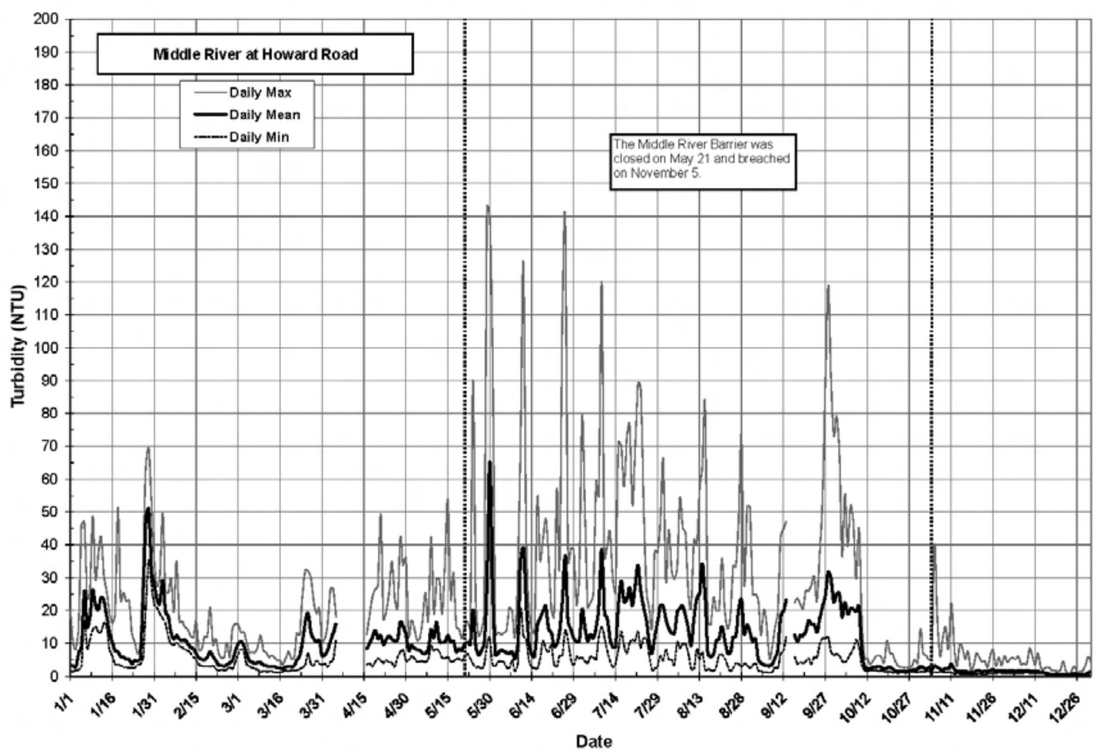
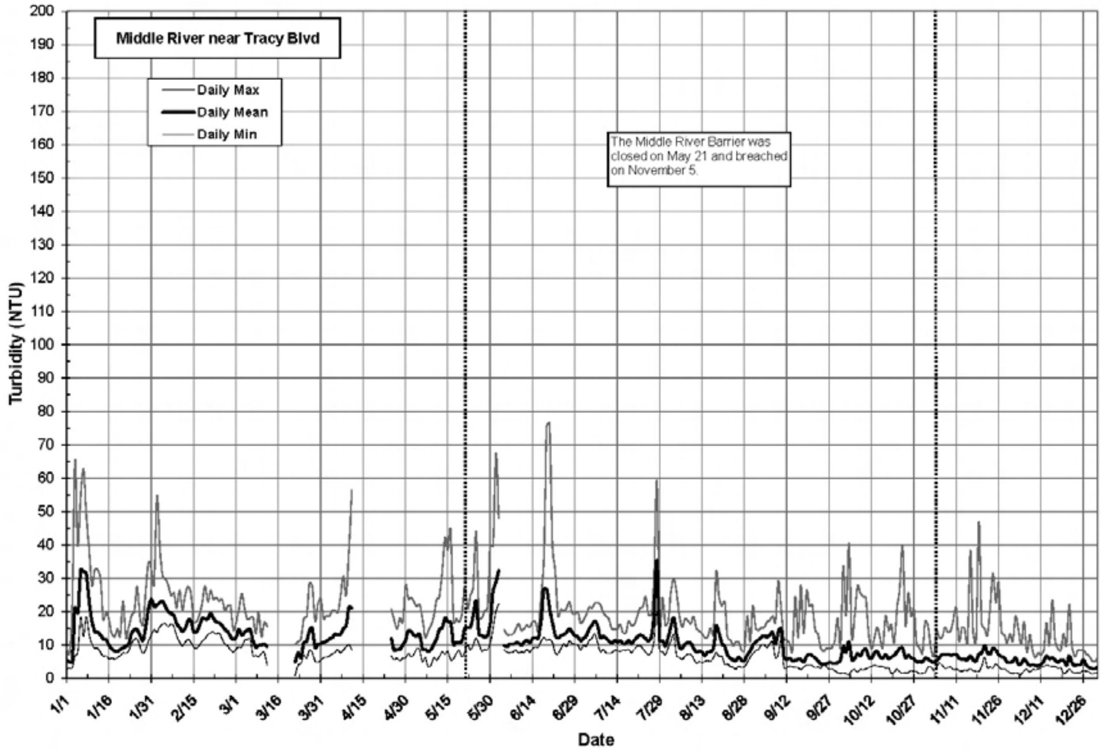


Figure 6-39. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) turbidity data



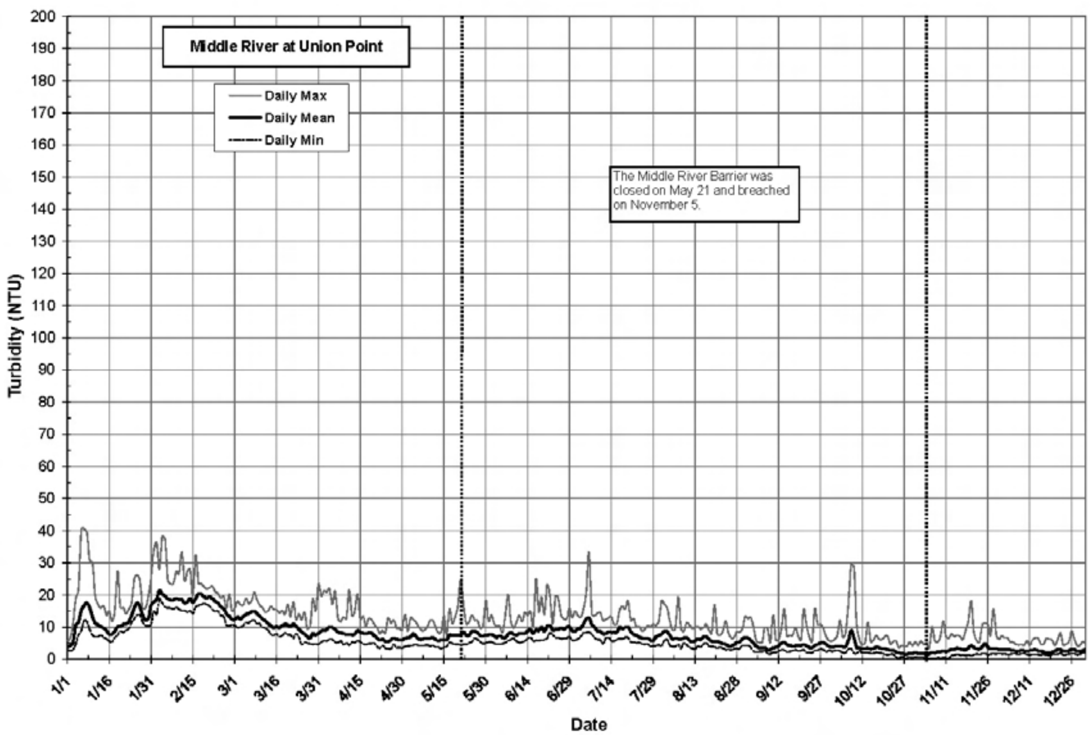
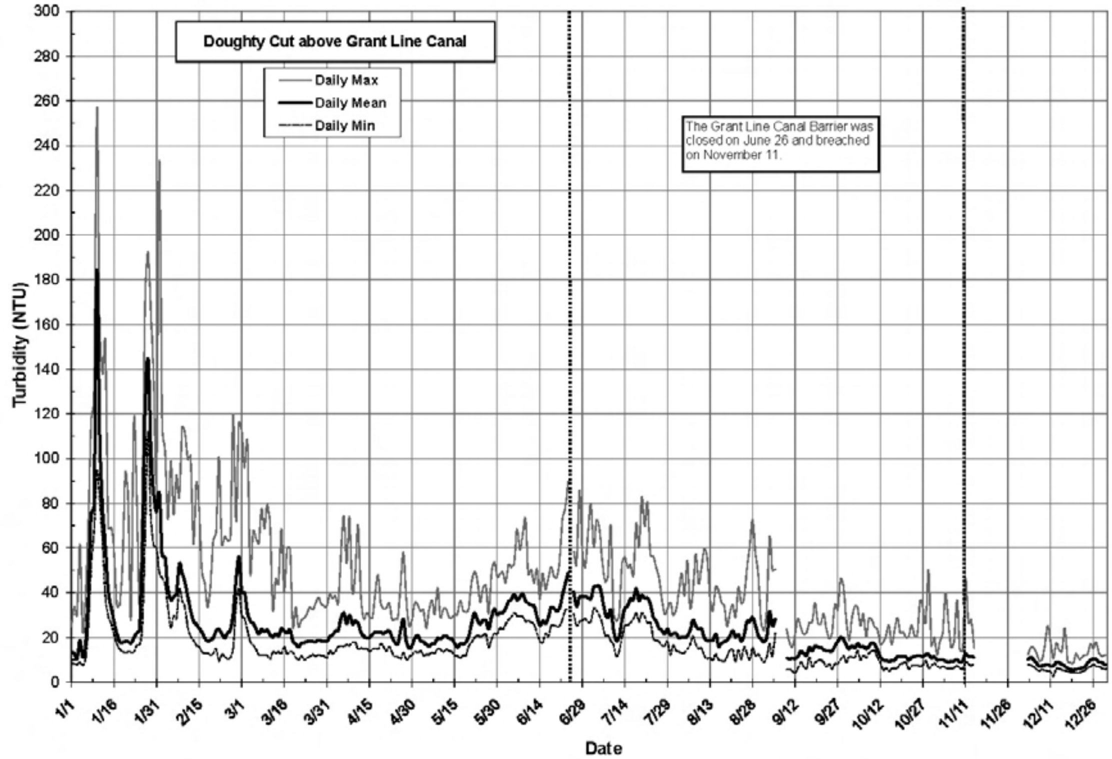


Figure 6-40. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) turbidity data



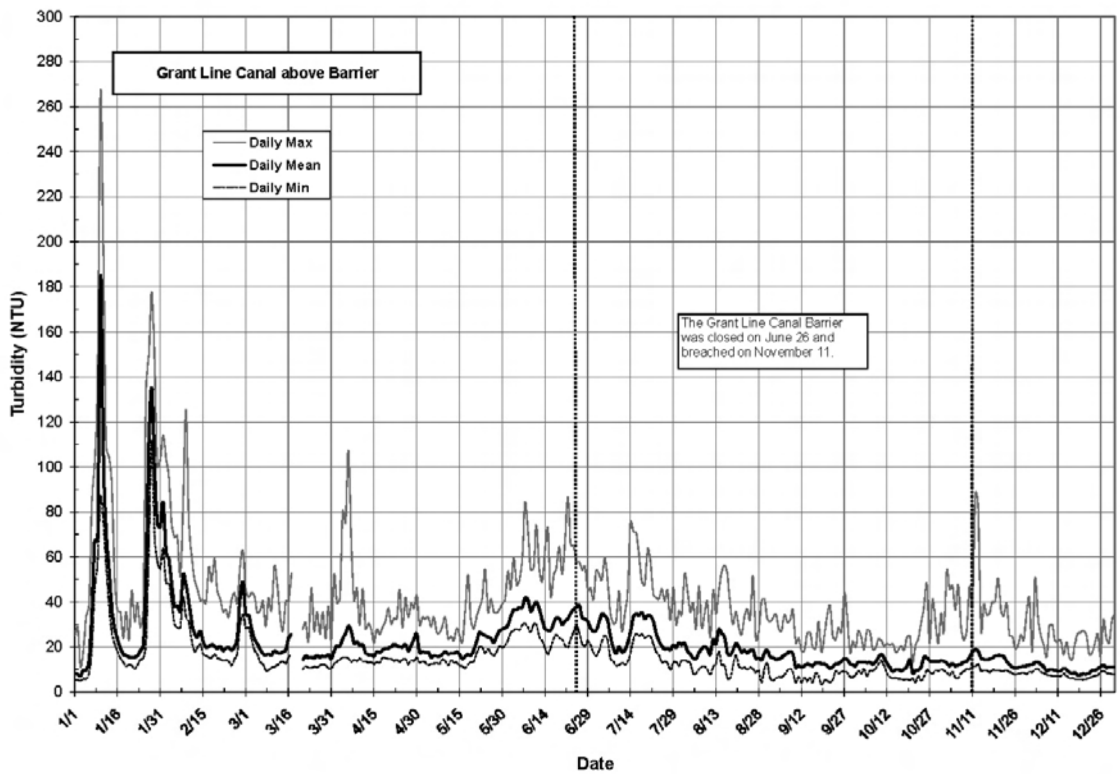
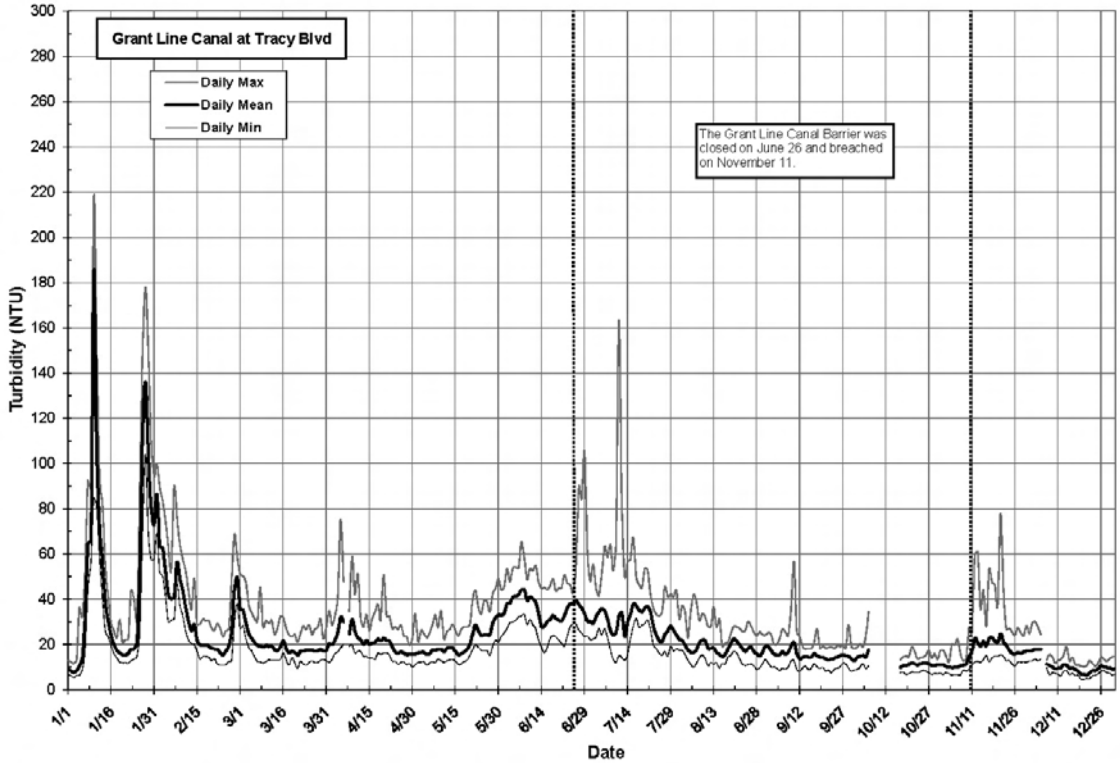


Figure 6-41. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) turbidity data



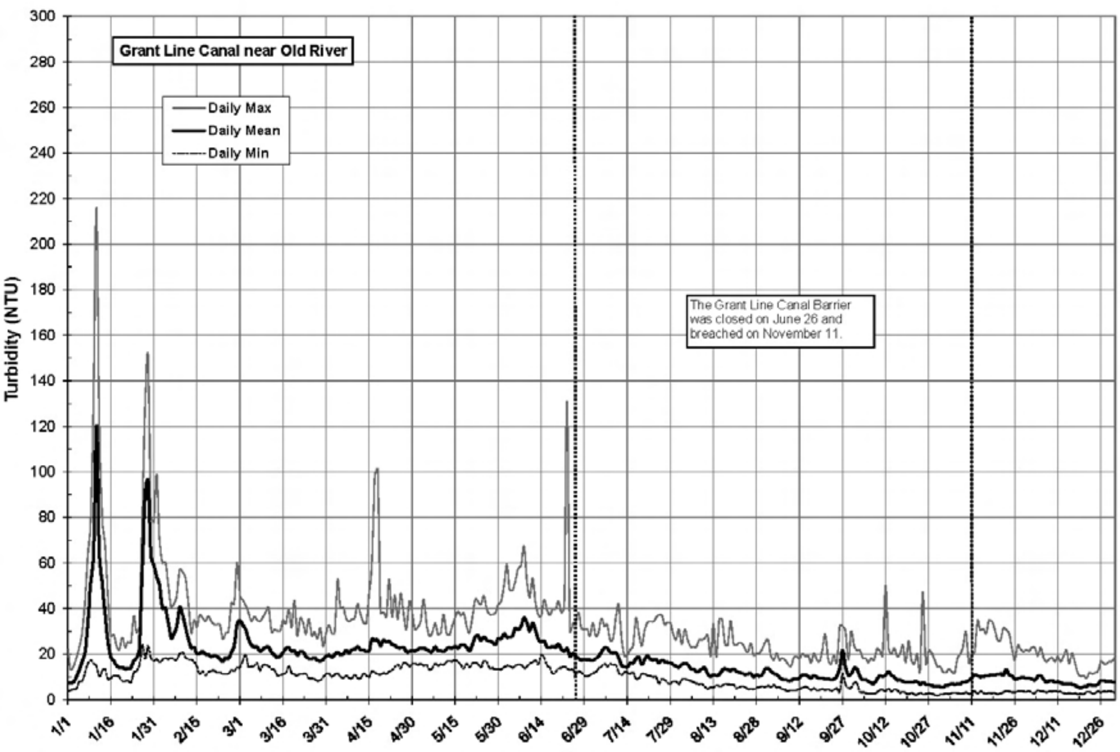
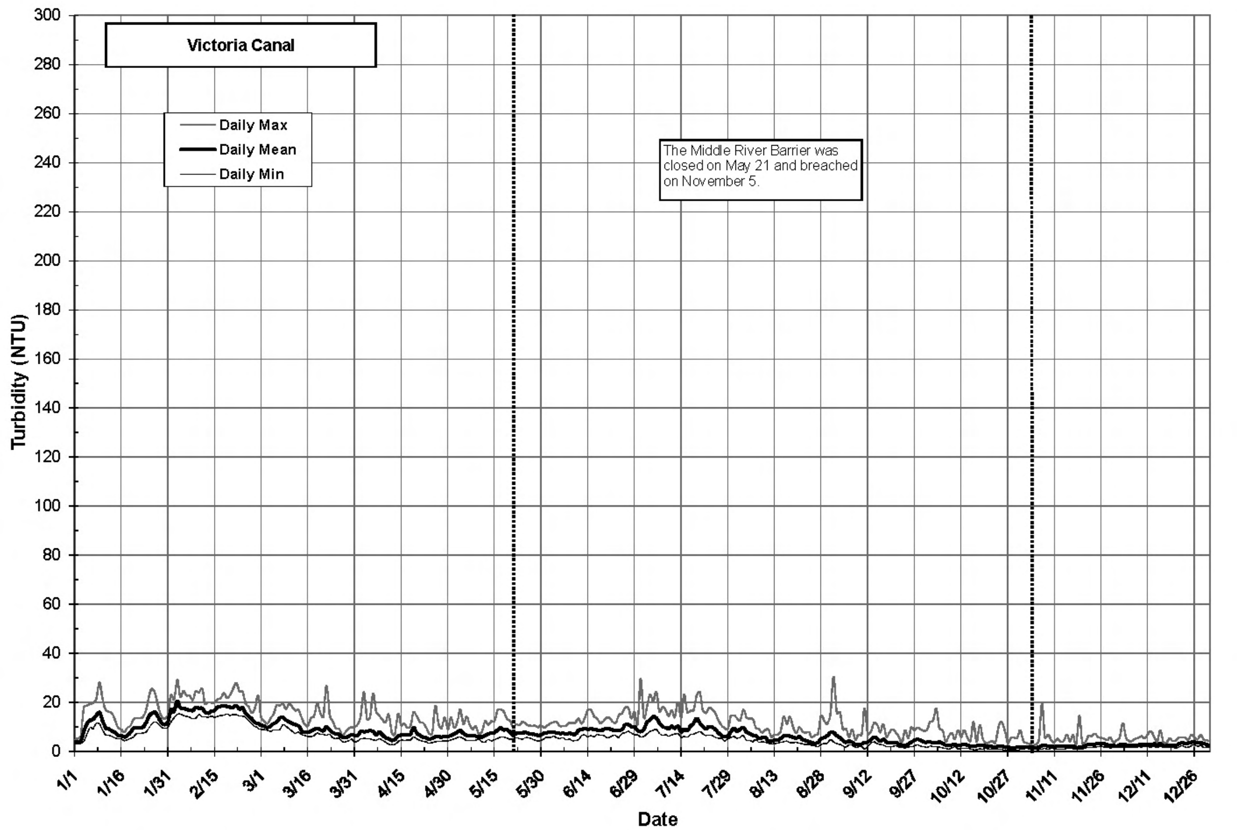


Figure 6-42. Victoria Canal daily (maximum, mean, minimum) turbidity data

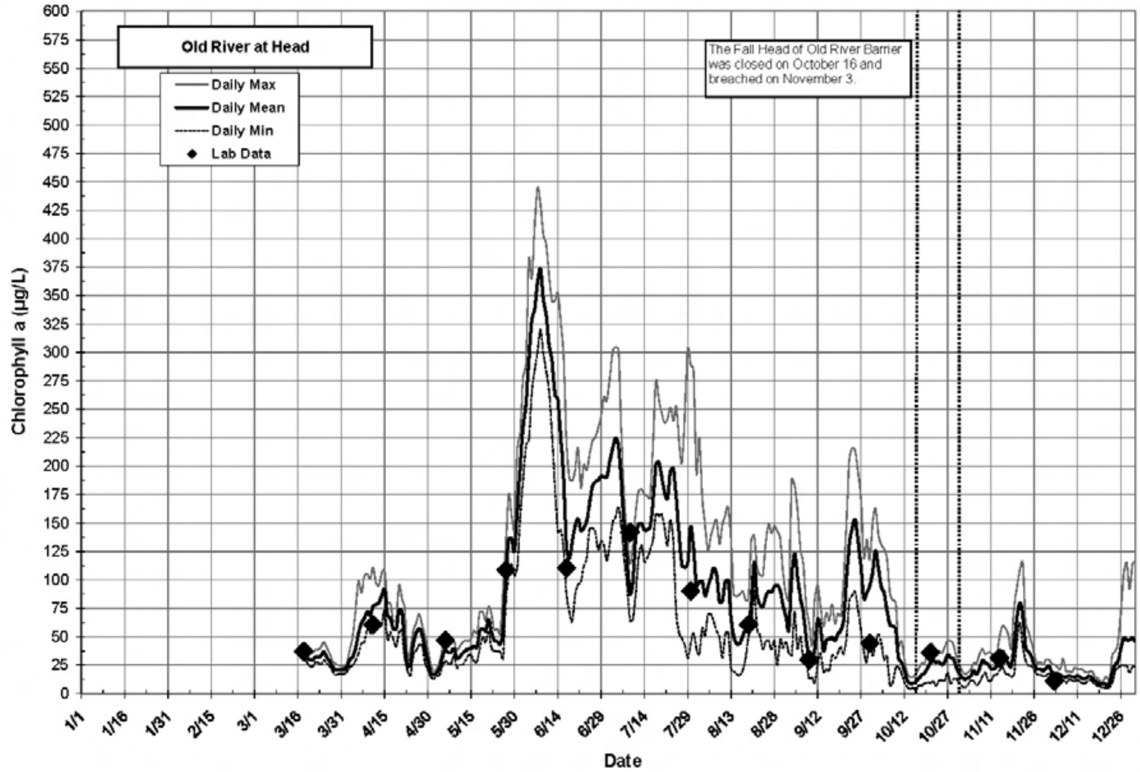


Chlorophyll *a*

Chlorophyll *a* concentrations can be used as an indicator of phytoplankton biomass in a water body (American Public Health Association 2005). Phytoplankton (microscopic algae) occur as unicellular, colonial, or filamentous forms and are primarily grazed upon by zooplankton and other aquatic organisms (American Public Health Association 2005). The species composition or biomass of phytoplankton may be a useful tool in assessing water quality (American Public Health Association 2005). Algae can influence water quality by affecting pH; DO; turbidity; and the color, taste and odor of water. Under certain conditions, some species can develop noxious blooms.

Winter (January, February, and December 2008). A maximum chlorophyll *a* concentration of 298.7 µg/L was measured on December 5 at Old River at Tracy Wildlife Association, and a minimum of 0.30 µg/L was recorded on January 3 at Old River upstream of the ORT barrier (Figures 6-43 to 6-49 and Tables 6-6 to 6-9). Monthly mean chlorophyll *a* concentrations during this time period ranged from 1.1 µg/L in January at Victoria Canal to 49.6 µg/L in December at Old River at Tracy Wildlife Association. Old River at Tracy Wildlife Association, Grant Line Canal above the GLC barrier, and Middle River at Undine Road were the only sites to have a monthly concentration of greater than 25.0 µg/L in winter. Winter chlorophyll *a* concentrations were the lowest of the 4 seasons.

Figure 6-43. Old River at head and Old River at Tracy Wildlife Association daily (maximum, mean, minimum) chlorophyll *a* data



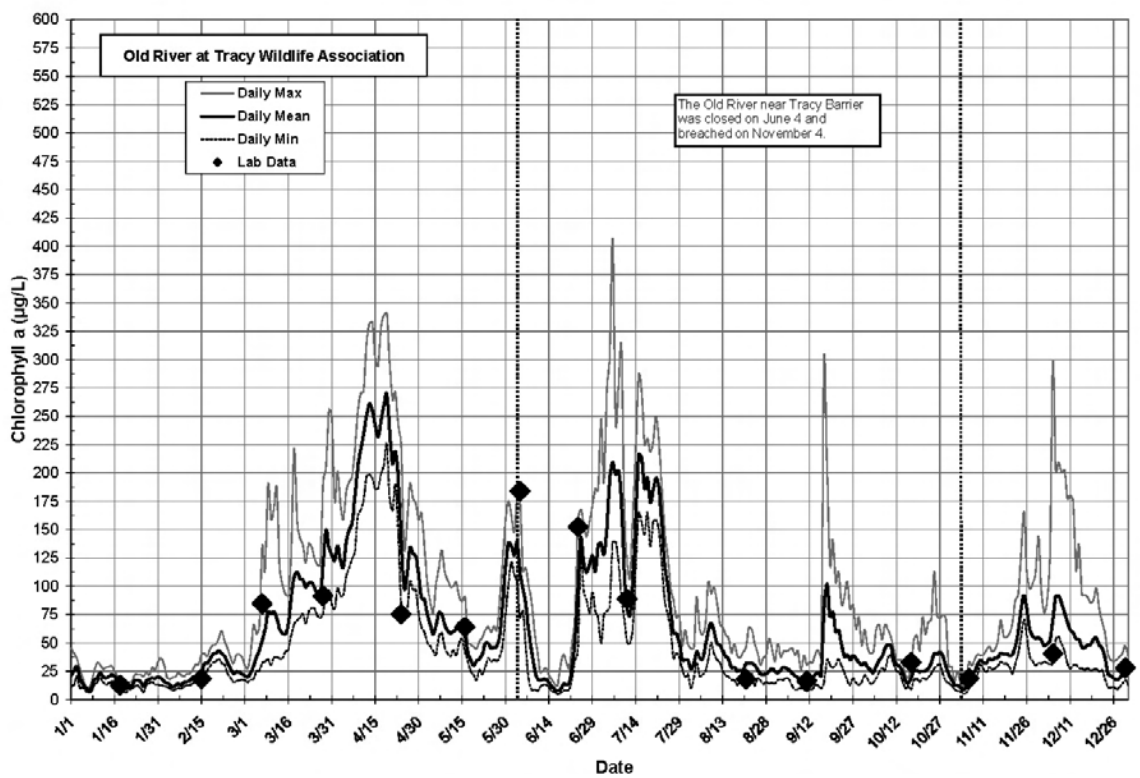


Figure 6-44. Old River upstream of the ORT barrier and Old River downstream of the ORT barrier daily (maximum, mean, minimum) chlorophyll *a* data

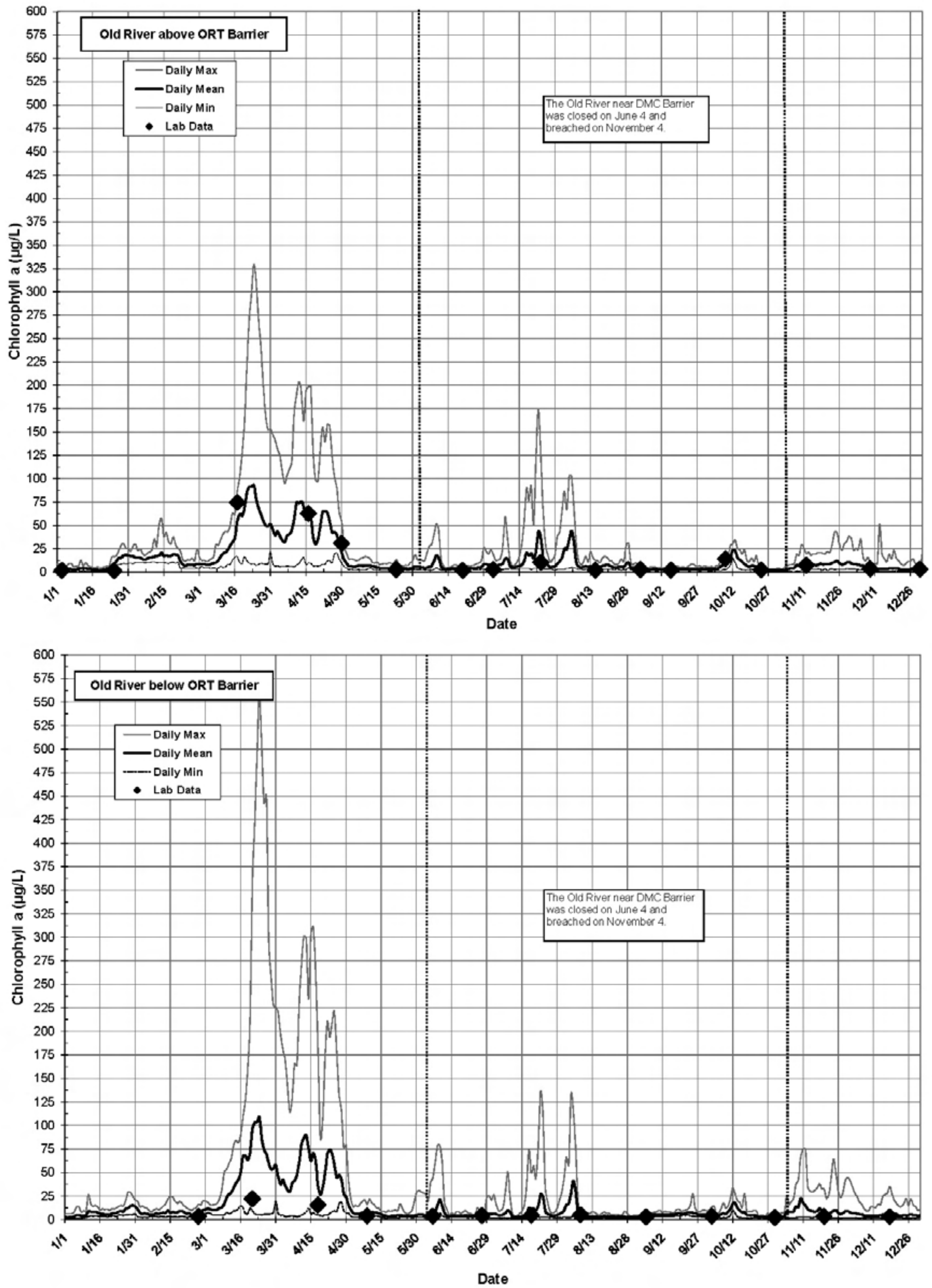
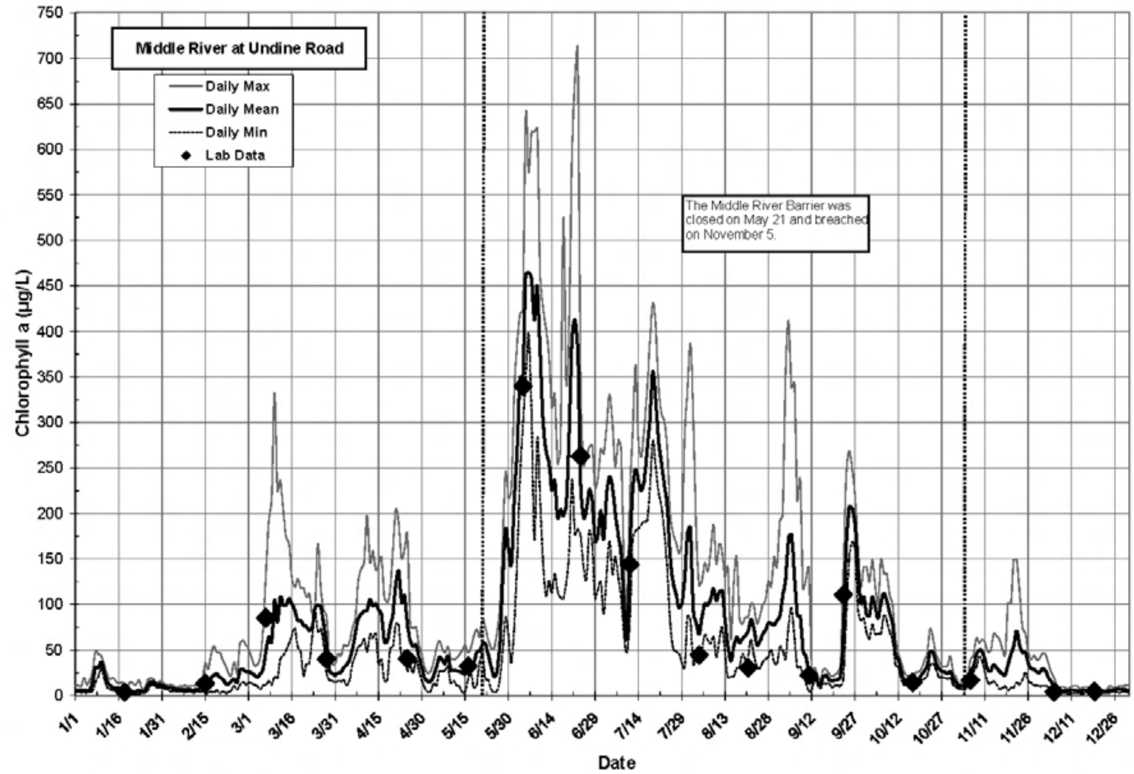


Figure 6-45. Middle River at Undine Road and Middle River at Howard Road daily (maximum, mean, minimum) chlorophyll *a* data



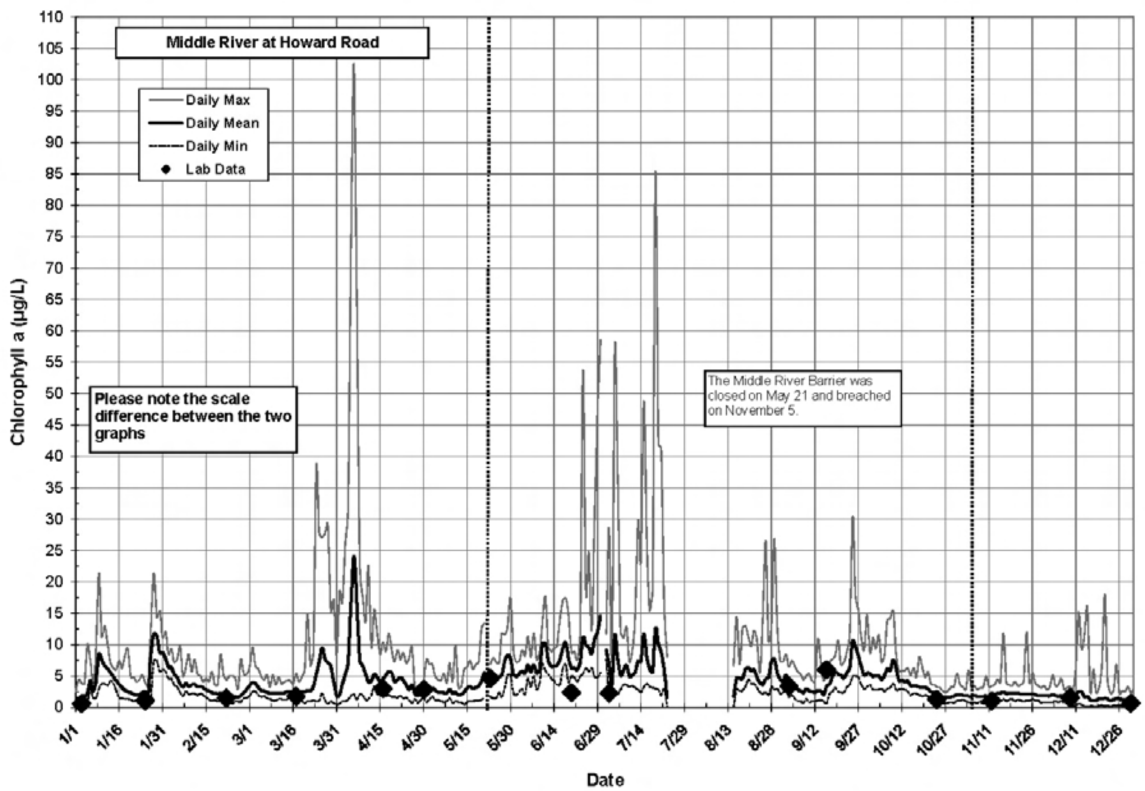
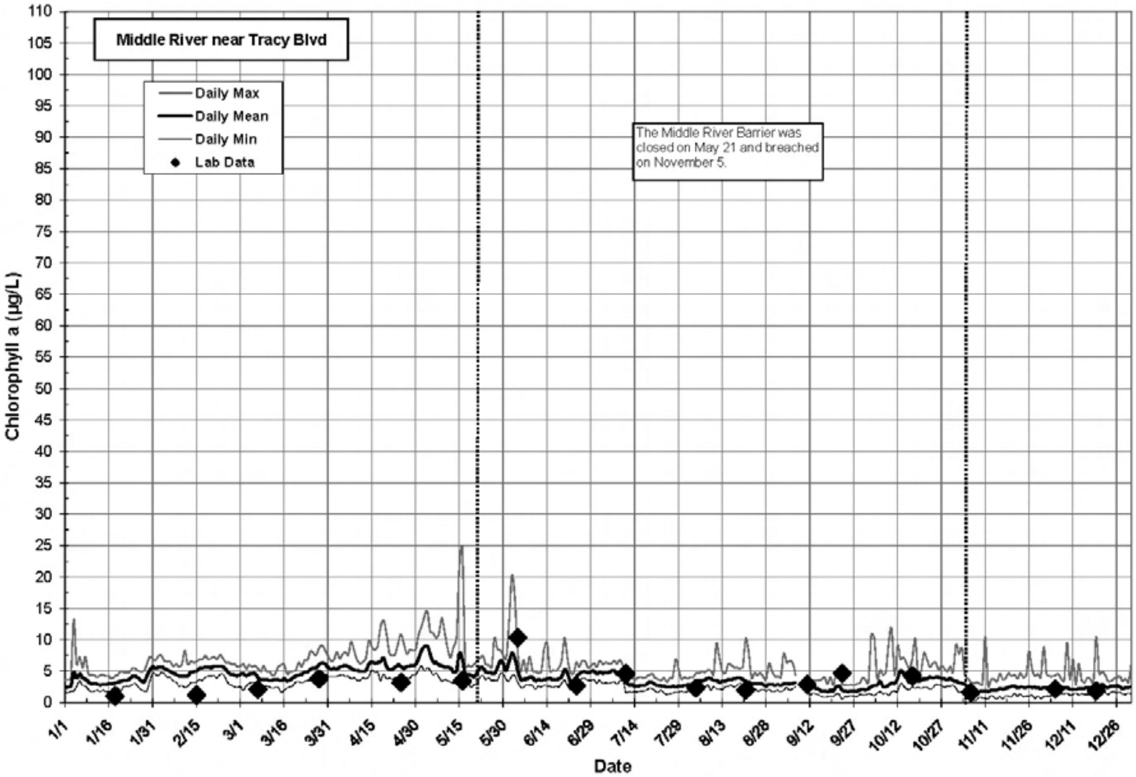


Figure 6-46. Middle River near Tracy Boulevard and Middle River at Union Point daily (maximum, mean, minimum) chlorophyll *a* data



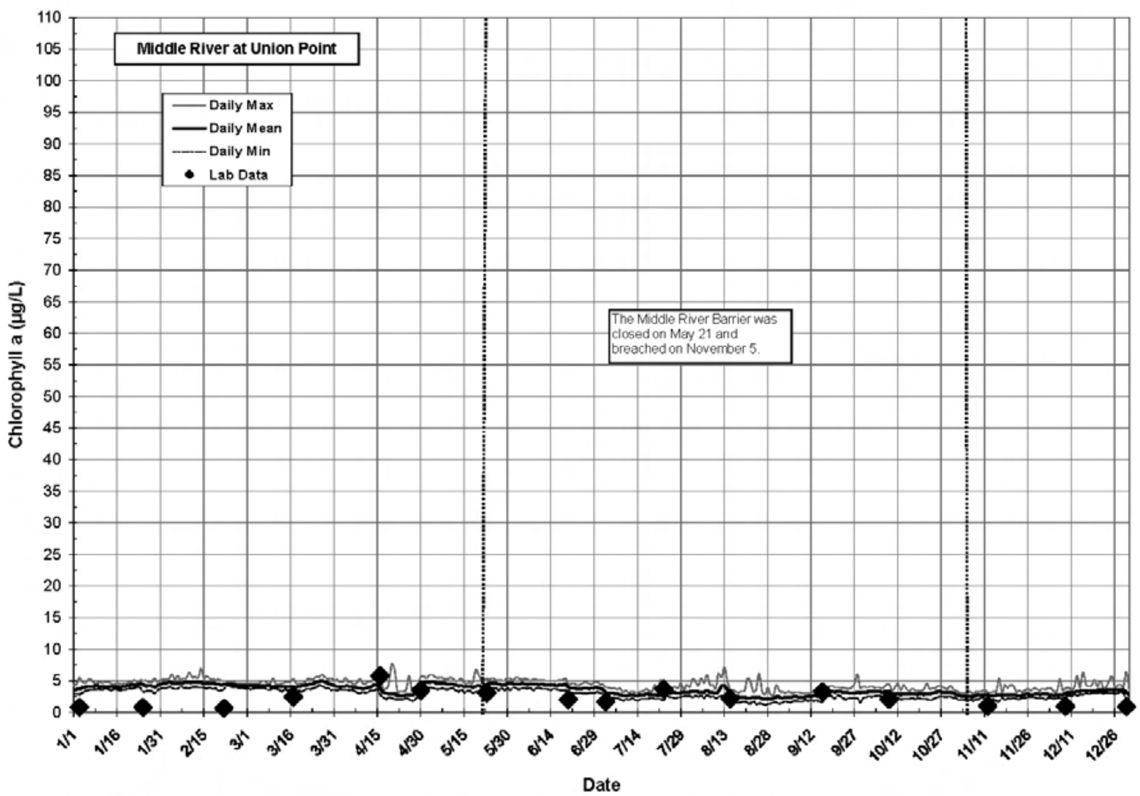
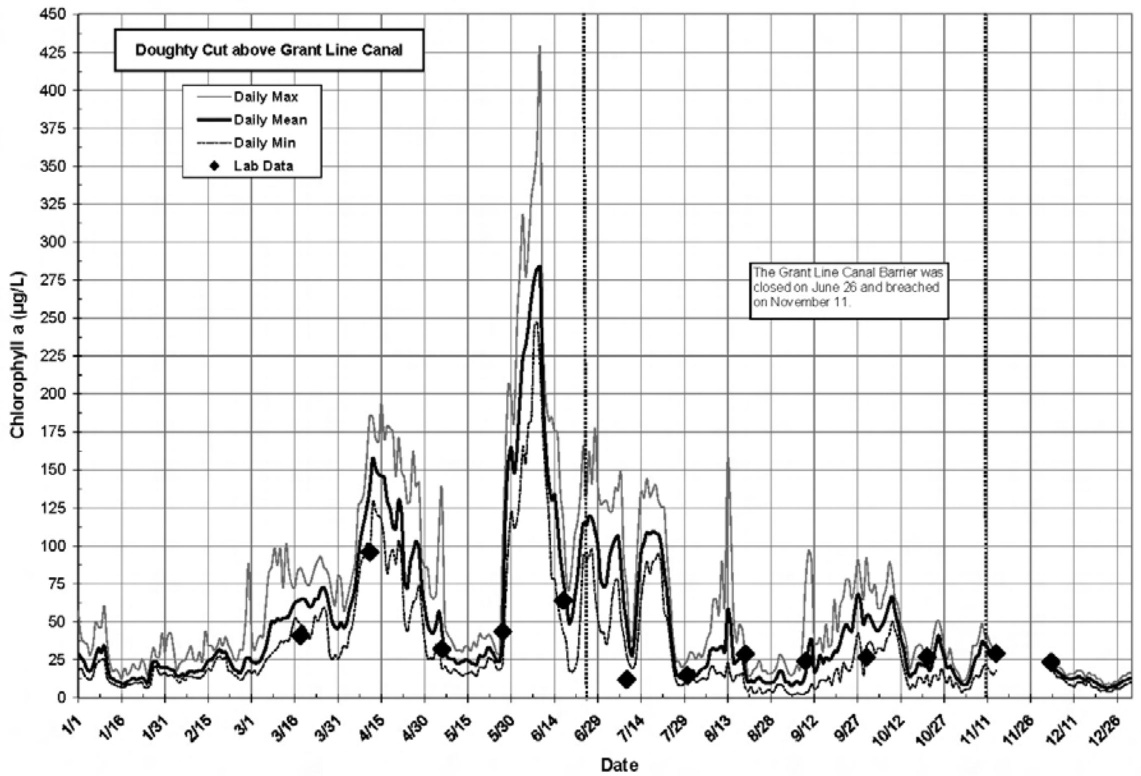


Figure 6-47. Doughty Cut above Grant Line Canal and Grant Line Canal above the GLC barrier daily (maximum, mean, minimum) chlorophyll *a* data



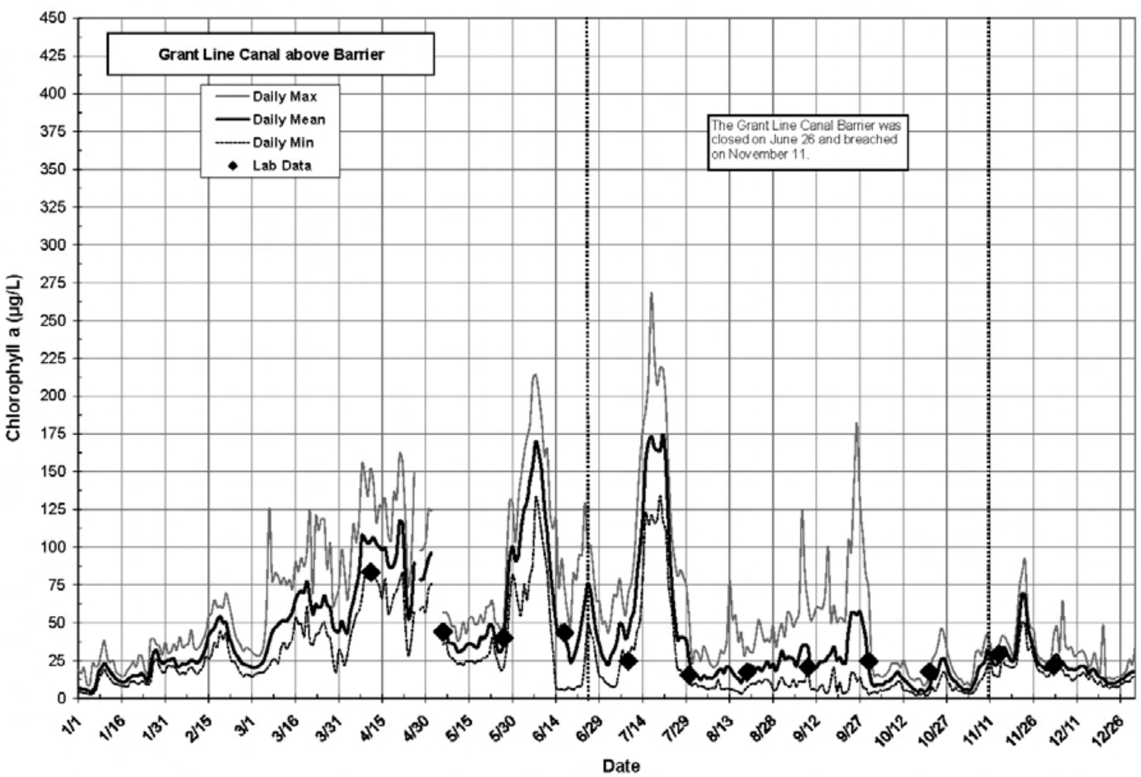
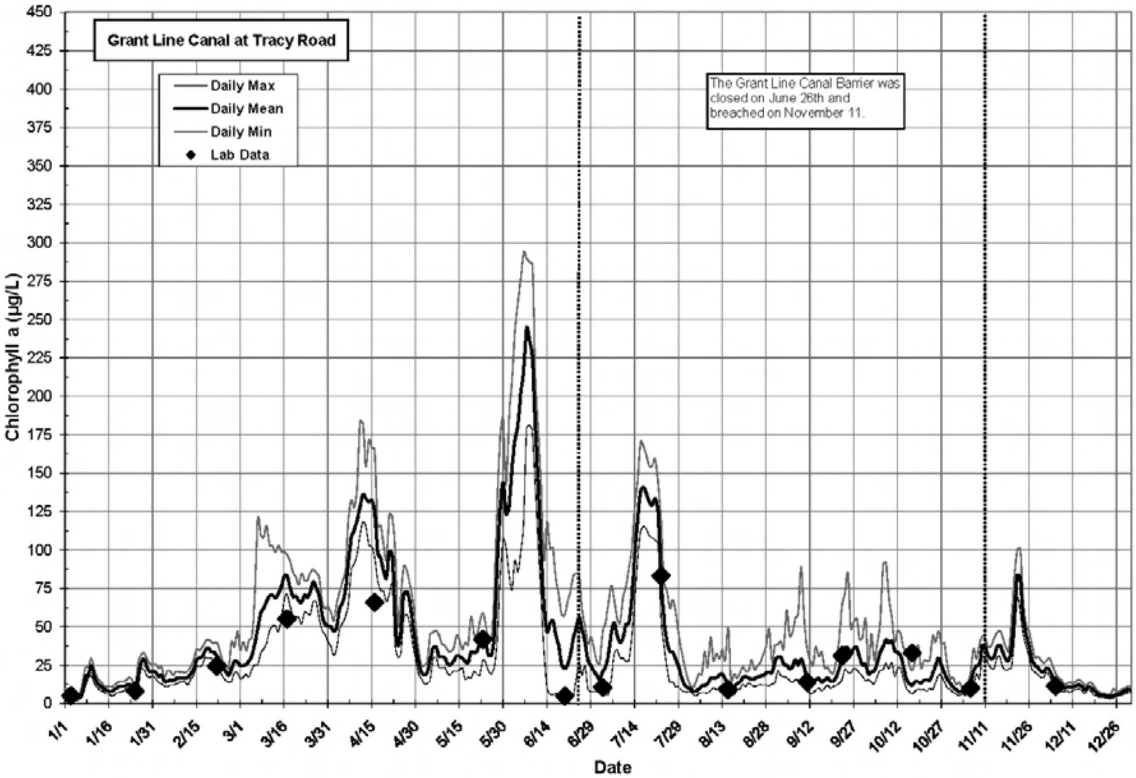


Figure 6-48. Grant Line Canal at Tracy Boulevard and Grant Line Canal near Old River daily (maximum, mean, minimum) chlorophyll *a* data



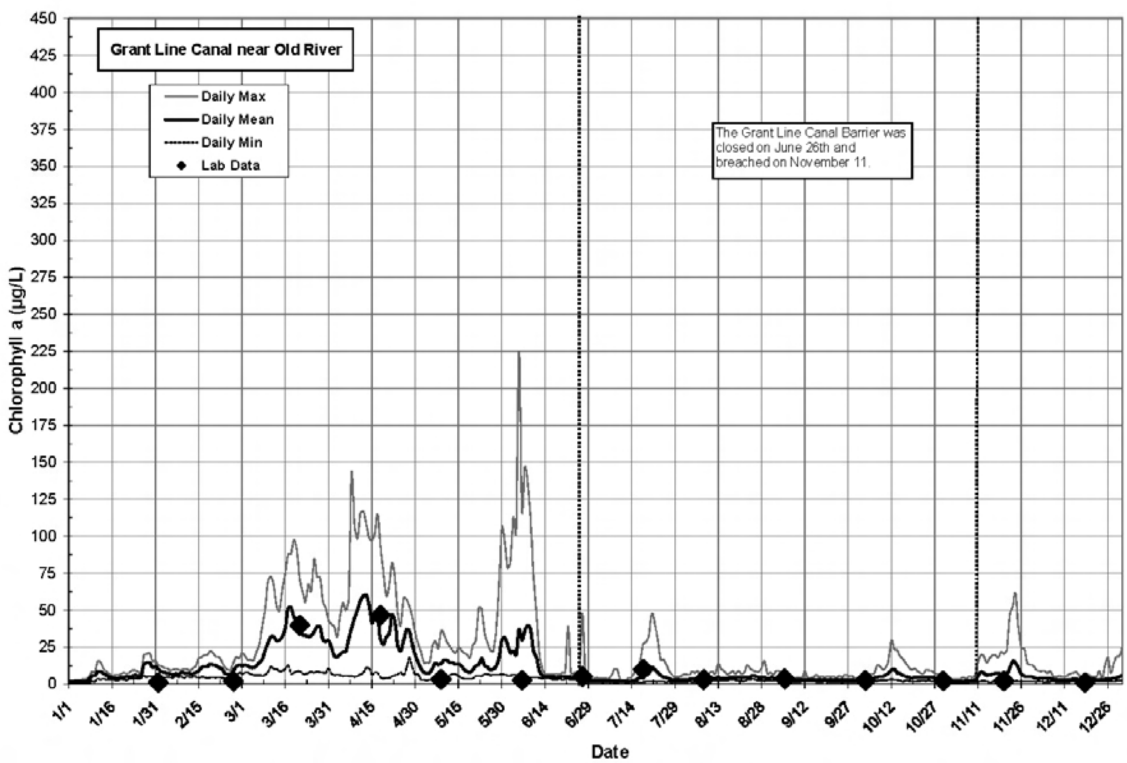
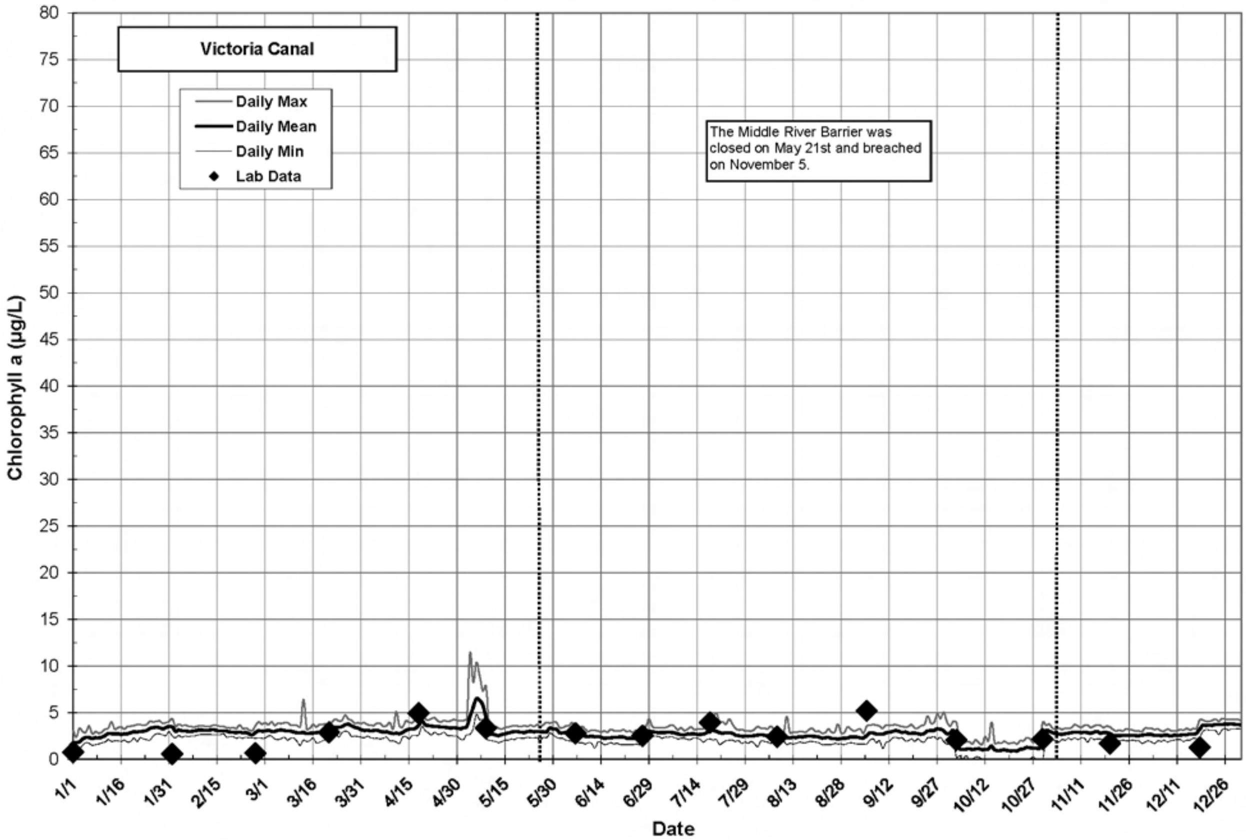


Figure 6-49. Victoria Canal daily (maximum, mean, minimum) chlorophyll *a* data



Spring (March–May 2008). A maximum chlorophyll *a* concentration of 341.1 µg/L was measured on April 19 at Old River at Tracy Wildlife Association, and a minimum of 0.4 µg/L was recorded on May 14 at Middle River at Howard Road. Monthly mean chlorophyll *a* concentrations during this time period ranged from 3.1 µg/L in March at Victoria Canal to 205.9 µg/L in May at Doughty Cut above Grant Line Canal. Eight of the 13 stations had monthly average chlorophyll concentrations in April of over 50 µg/L (Old River near head, Old River at Tracy Wildlife Association, Old River upstream of the ORT barrier, Old River downstream of the ORT barrier, Middle River at Undine Road, Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Boulevard). Grant Line Canal near Old River had an average chlorophyll *a* concentration in April of 37.5 µg/L. The lowest chlorophyll *a* concentrations were observed at Middle River at Howard Road, Middle River near Tracy Boulevard, Middle River at Union Point, and Victoria Canal, where average monthly concentrations did not exceed 10 µg/L.

Summer (June–August 2008). A maximum chlorophyll *a* concentration of 709.9 µg/L was measured on June 23 at Middle River at Undine Road, and a minimum of 0.9 µg/L was recorded on July 28 at Grant Line Canal near Old River. Monthly mean chlorophyll *a* concentrations during this time period ranged from 2.4 µg/L in August at Victoria Canal to 294.8 µg/L in June at Middle River at Undine Road. Chlorophyll *a* concentrations were highest during the year in the months of June and July, with the highest concentrations measured at Old River near head and Middle River at Undine Road (228.3 µg/L and 294.8 µg/L). Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, Grant Line Canal at Tracy Boulevard, and Old River at Tracy Wildlife Association had average chlorophyll *a* concentrations ranging from 80.9 µg/L to 146.6 µg/L. The lowest chlorophyll *a* concentrations were observed at Middle River at Howard Road, Middle River near Tracy Boulevard, Middle River at Union

Point, Victoria Canal, Grant Line Canal near Old River, Old River upstream of the ORT barrier, and Old River downstream of the ORT barrier, where average monthly concentrations did not exceed 15 µg/L. Summer chlorophyll *a* concentrations were the highest of the 4 seasons.

Fall (September–November 2008). A maximum chlorophyll *a* concentration of 411.6 µg/L was measured on September 4 at Middle River at Undine Road, and a minimum of 0.3 µg/L was recorded on November 7 at Middle River near Tracy Boulevard. Monthly mean chlorophyll *a* concentrations during this time period ranged from 2.0 µg/L in November at Middle River at Howard Road to 81.3 µg/L in September at Middle River at Undine Road. Monthly chlorophyll *a* concentrations were highest during September and lowest in November. Old River near head, Old River at Tracy Wildlife Association, Middle River at Undine Road, Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Boulevard had the highest chlorophyll *a* concentrations in September, with values ranging from 30.5 µg/L to 81.3 µg/L. The lowest chlorophyll *a* concentrations were observed at Middle River at Howard Road, Middle River near Tracy Boulevard, Middle River at Union Point, Victoria Canal, Grant Line Canal near Old River, Old River upstream of the ORT barrier, and Old River downstream of the ORT barrier, where average monthly concentrations did not exceed 10.6 µg/L.

The estimated chlorophyll *a* data and the seasonal patterns seen in the continuous data are further corroborated by additional chlorophyll *a* samples collected by DWR's Surface Water Data Section (Figures 6-50 to 6-52).

Figure 6-50. Old River: chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data

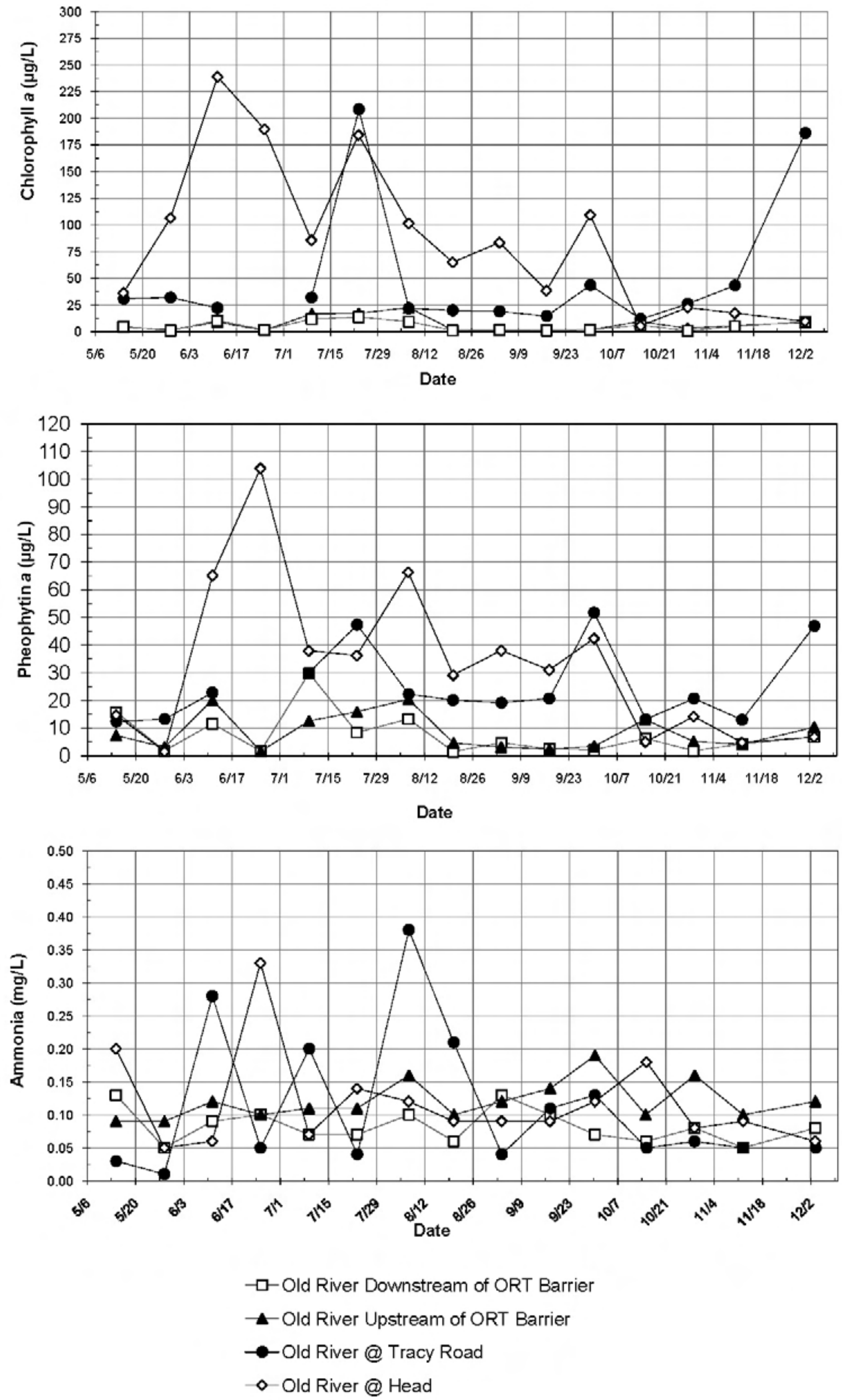


Figure 6-51. Middle River chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data

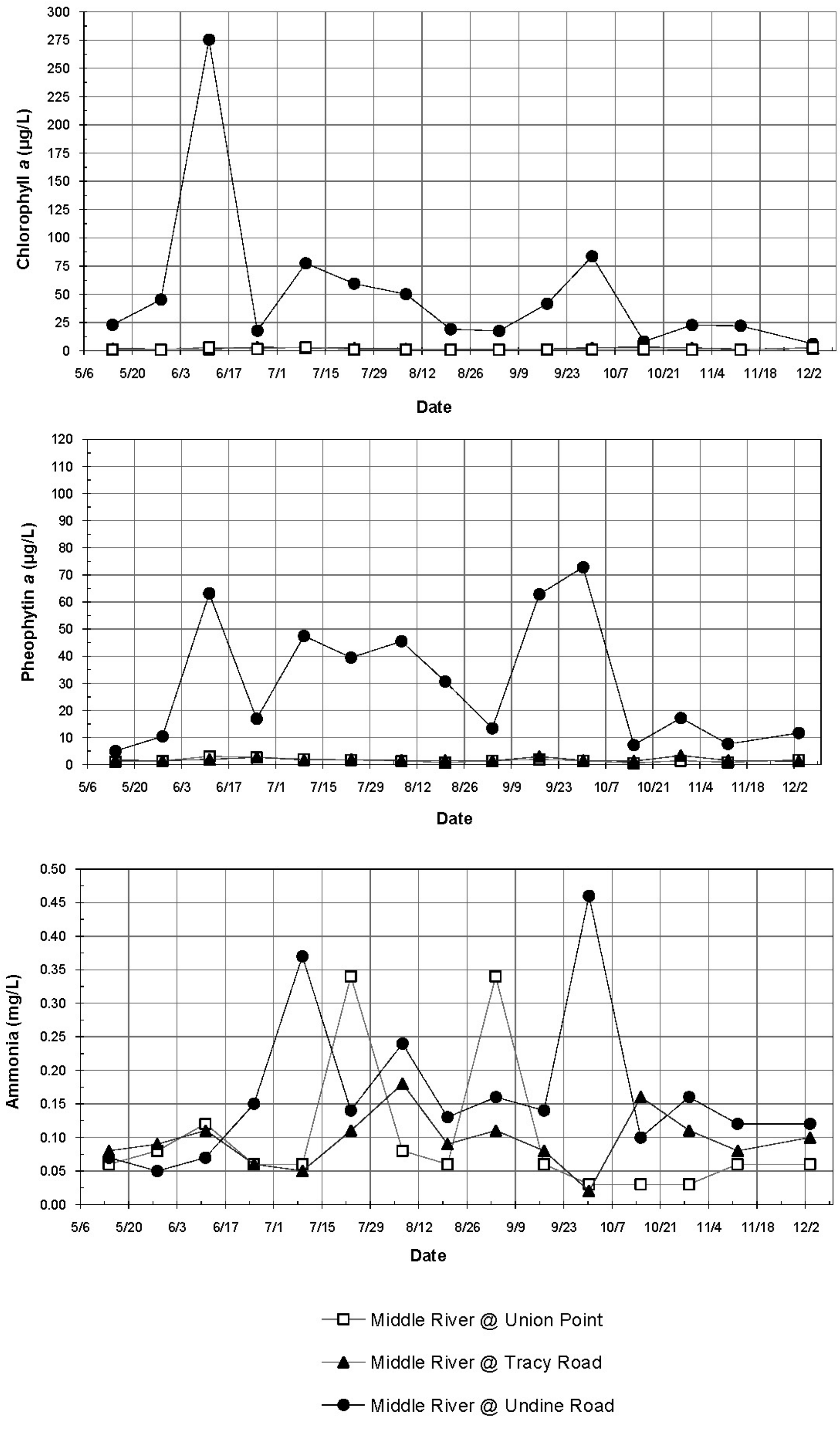
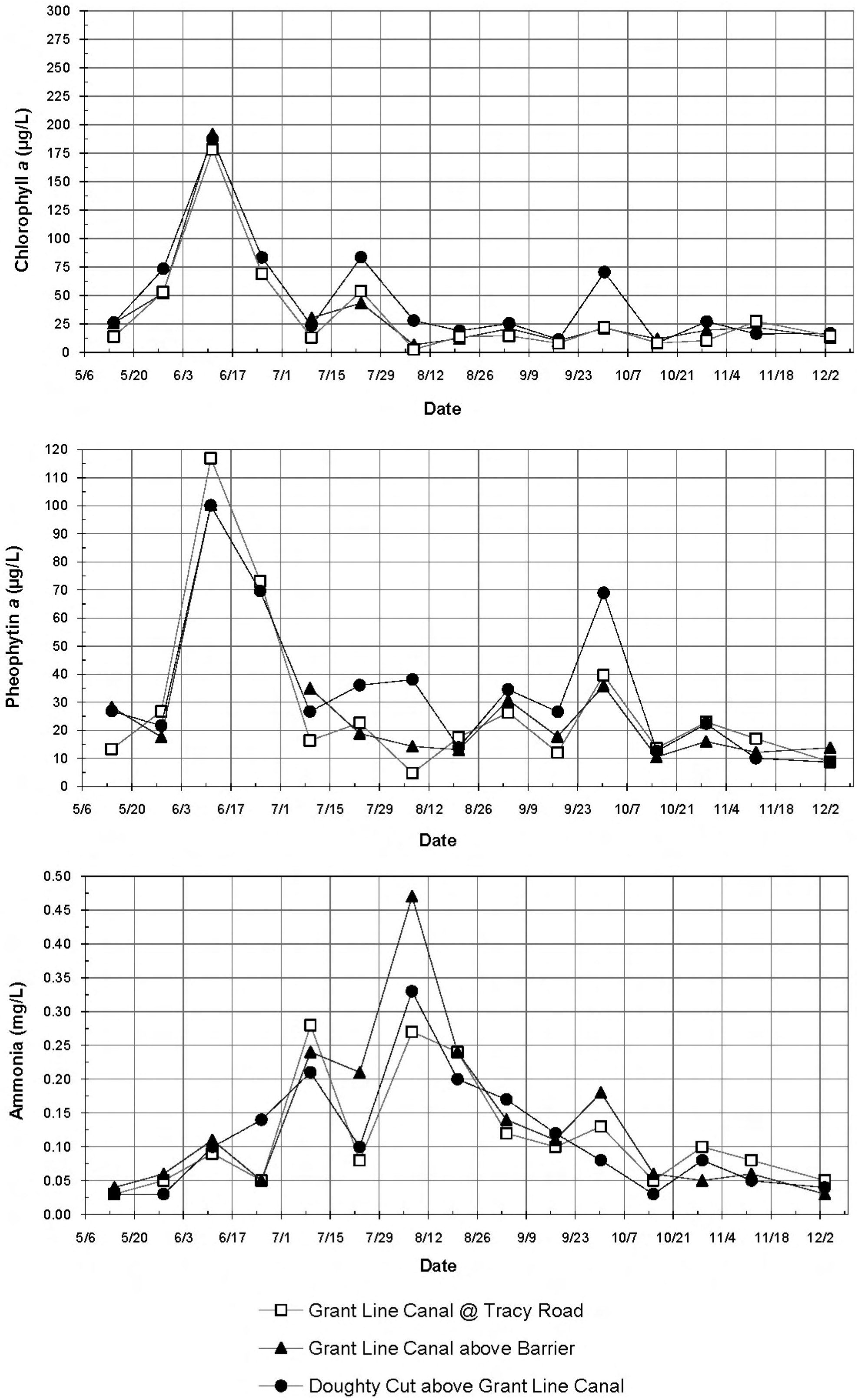


Figure 6-52. Grant Line Canal chlorophyll *a*, pheophytin *a*, and ammonia discrete water quality data



Pheophytin *a*

As phytoplankton populations decline, chlorophyll *a* degrades into byproducts. Pheophytin *a* is a degradation product of chlorophyll *a*. When phytoplankton is actively growing, the concentrations of pheophytin *a* are normally expected to be low in relation to chlorophyll *a*. The sonde chlorophyll probe measures all chlorophyll and can be influenced by high turbidity values (> 100 NTU) as well, so it is important to take a grab sample and have it analyzed for chlorophyll *a* and pheophytin *a*.

Generally, pheophytin *a* concentrations were highest during the summer and lowest in November, mirroring chlorophyll *a* concentrations (see Figures 6-50 to 6-52). (Refer also to Figure 6-1 for discrete station locations.) A maximum pheophytin *a* concentration of 117 µg/L was recorded on June 11, 2008, at Grant Line Canal at Tracy Boulevard, and a minimum of 0.61 µg/L was recorded on October 15, 2008, at Middle River at Union Point. Average pheophytin *a* concentrations were highest during the monitoring period at Old River at head (31.0 µg/L), Old River at Tracy Boulevard (20.7 µg/L), Middle River at Undine Road (30.1 µg/L), Doughty Cut above Grant Line Canal (34.4 µg/L), Grant Line Canal above the GLC barrier (26.0 µg/L), and Grant Line Canal at Tracy Boulevard (28.7 µg/L), where the largest chlorophyll *a* concentrations were observed. The remaining sites (Middle River near Tracy Boulevard, Middle River at Union Point, and Old River both upstream and downstream of the ORT barrier) had average pheophytin *a* concentrations of less than 10.0 µg/L, paralleling average chlorophyll *a* concentrations.

Ammonia

Ammonia is present naturally in surface and wastewaters. It is produced largely by deamination of organic nitrogen containing compounds and is sometimes used by wastewater treatment plants to react with chlorine (American Public Health Association 2005). High ammonia concentrations in natural surface water may indicate contamination from effluent.

Discrete samples of ammonia concentrations in the south Delta ranged from a minimum of 0.01 mg/L to a maximum of 0.47 mg/L (see Figures 6-50 to 6-52). Average concentrations during the monitoring period ranged from a low of 0.08 mg/L at Old River downstream of the ORT barrier to a high of 0.17 mg/L at Middle River at Undine Road. Ammonia concentrations at the stations on Grant Line Canal and Doughty Cut peaked in the beginning of August. On Middle River, the average concentrations of ammonia peaked from July through early October. The Old River sites had varying peaks of ammonia.

Ammonia concentrations at Old River at Tracy Boulevard peaked from June to August, and ammonia concentrations at Old River at head peaked in late June and early July. The other 2 sites, Old River both upstream and downstream of the ORT barrier, had fairly steady ammonia concentrations, with a slight peak in late September and early October.

Nitrite + Nitrate

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate is an essential nutrient for many photosynthetic autotrophs (plants and algae) and can be a growth-limiting nutrient. Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation of ammonia to nitrate and in the reduction of nitrate (American Public Health Association 2005).

Nitrite + nitrate concentrations in the south Delta ranged from a minimum of 0.16 mg/L to a maximum of 3.40 mg/L (Figures 6-53 to 6-55). Average concentrations during the monitoring period ranged from a low of 0.16 mg/L at Old River at Tracy Boulevard to a high of 1.53 mg/L at Middle River at Undine Road. South Delta nitrite + nitrate concentrations in Old River, Grant Line Canal, Doughty Cut, and Middle River at Undine Road were elevated from September through December averaging. Old River and Grant Line Canal showed little variation between sites in comparison with Middle River. In Middle River, the Undine Road monitoring site had consistently higher nitrite + nitrate concentrations from August through November. All nitrite + nitrate levels were below the California Public Health Goal of 10 mg/L (Polakoff 1997).

Figure 6-53. Old River nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data

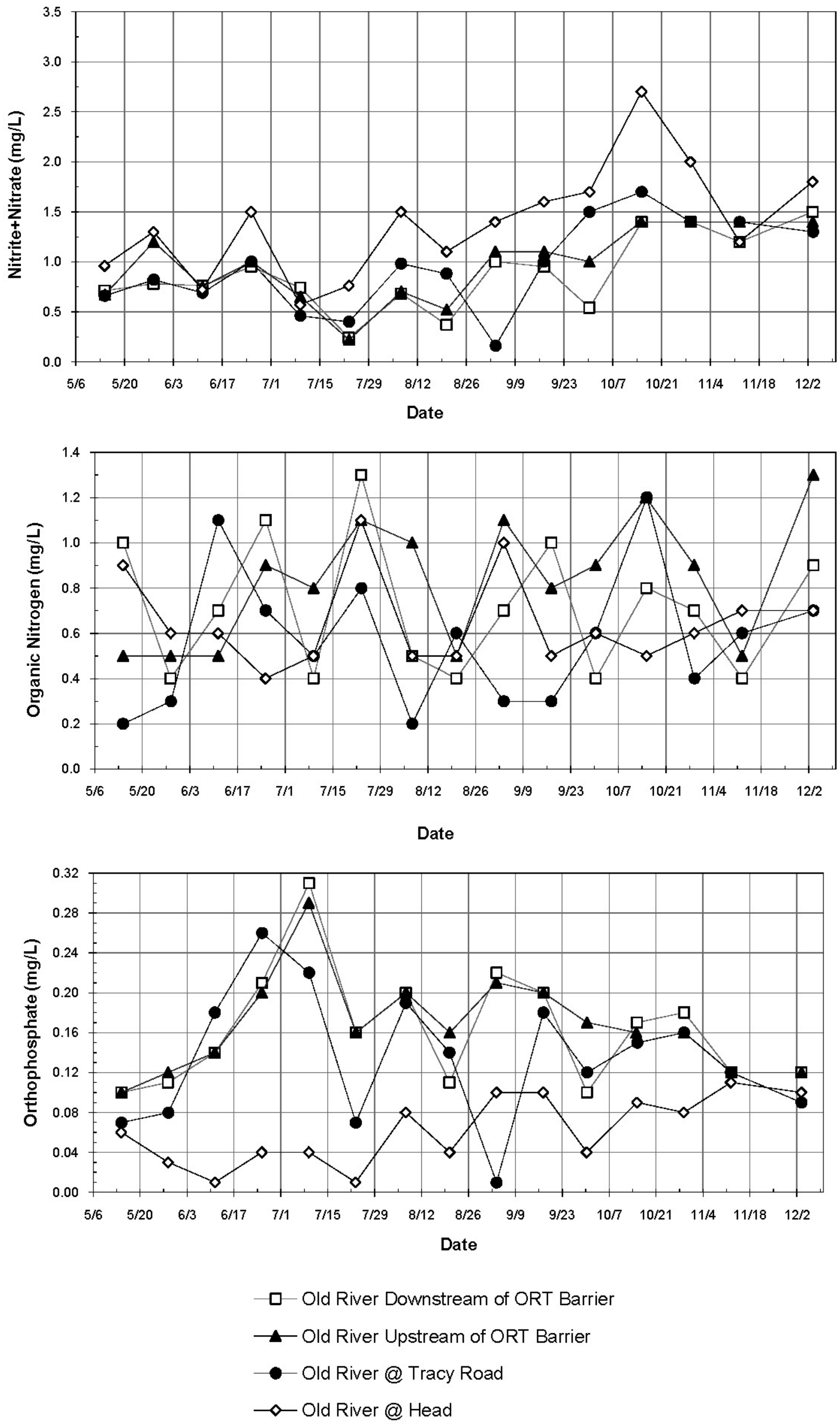


Figure 6-54. Middle River nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data

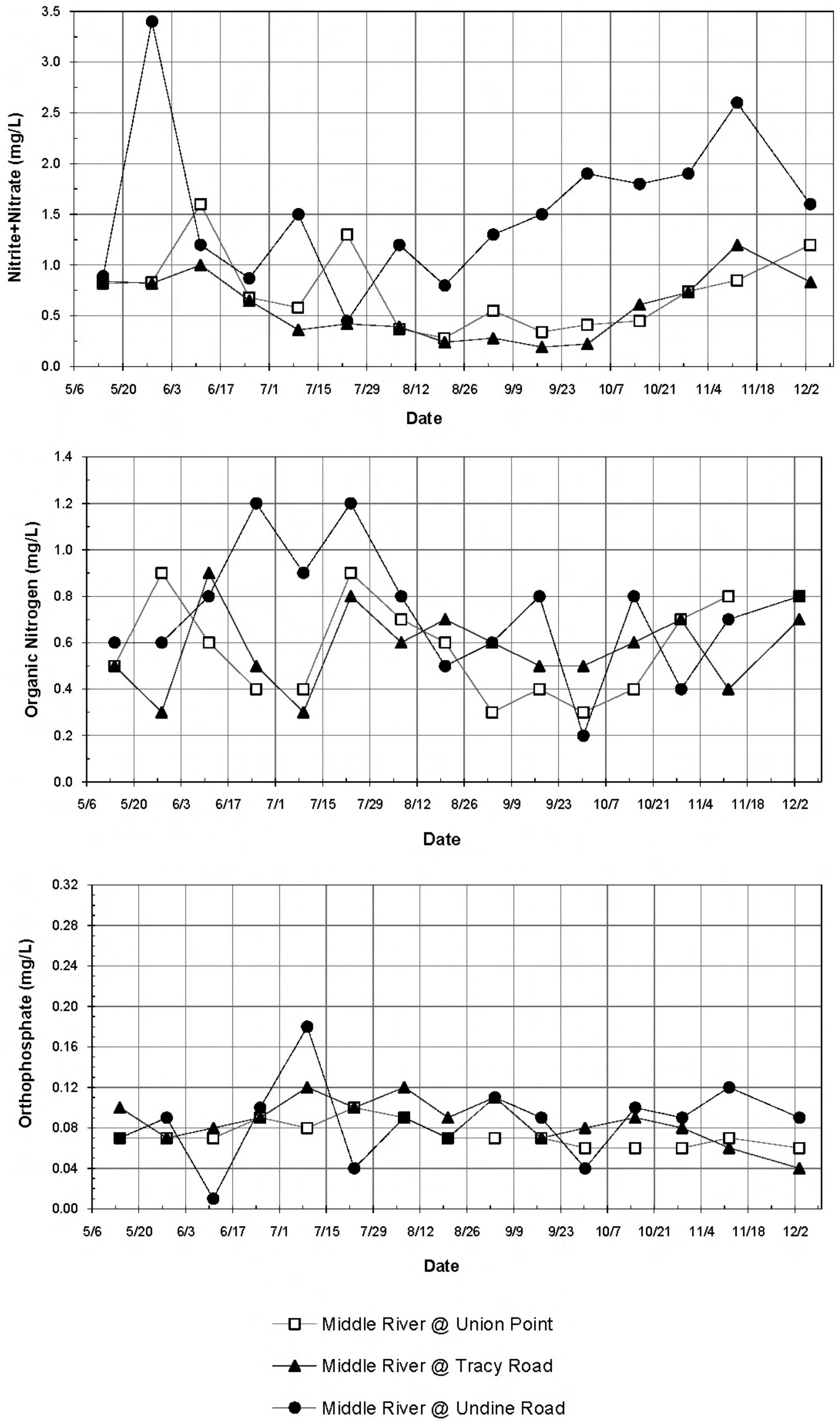
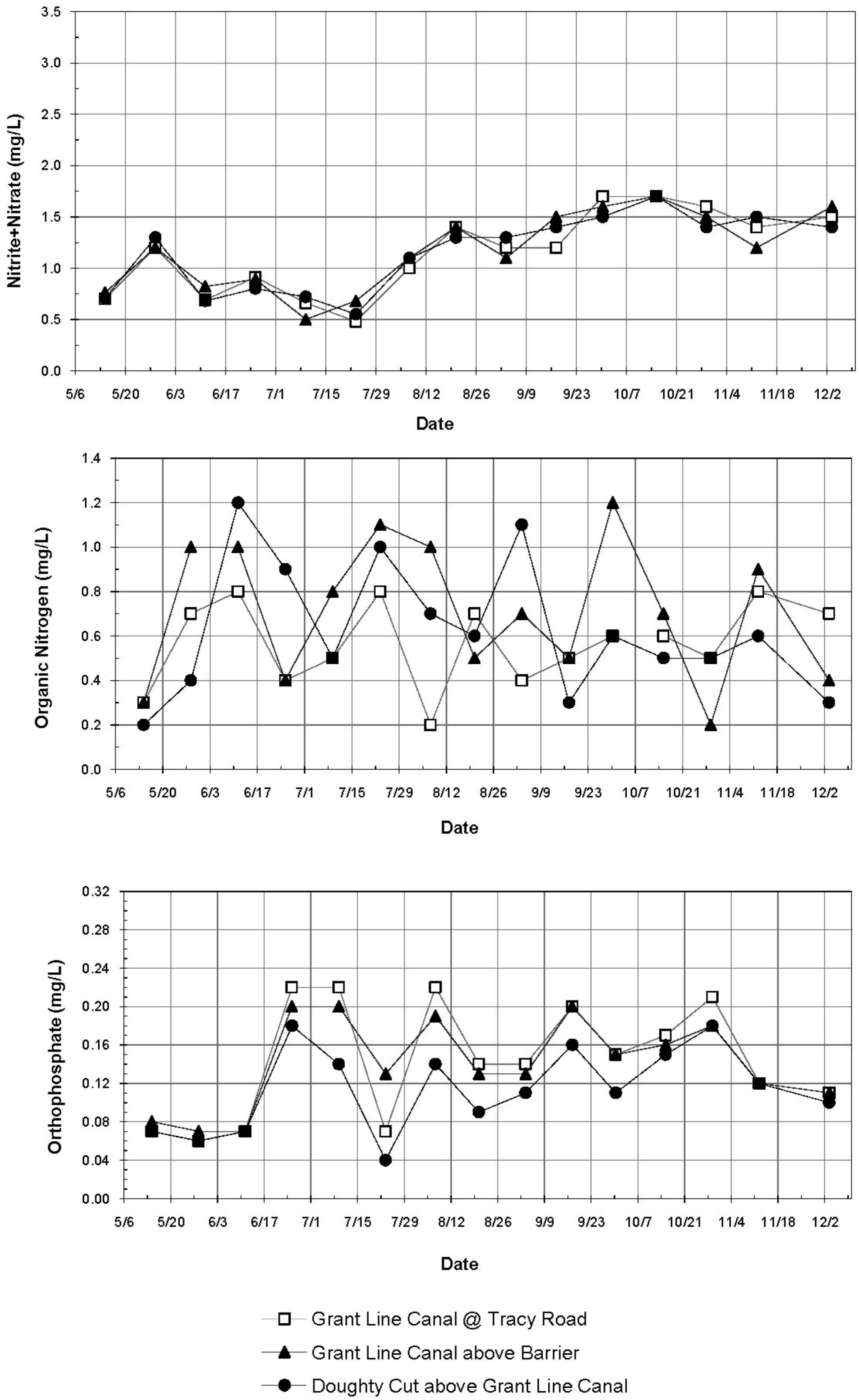


Figure 6-55. Grant Line Canal nitrite + nitrate, organic nitrogen, and orthophosphate discrete water quality data



Organic Nitrogen

Organic nitrogen is a component in the nitrogen cycle along with nitrite, nitrate, ammonia, and nitrogen gas and is defined functionally as organically bound nitrogen in the trinegative oxidation state. Organic nitrogen includes such materials as proteins and peptides, nucleic acids and urea, and numerous synthetic organic materials. Organic nitrogen concentrations can range from a few hundred micrograms per liter in some lakes to more than 20 mg/L in raw sewage (American Public Health Association 2005).

Organic nitrogen concentrations in the south Delta ranged from 0.2 mg/L to 1.3 mg/L (Figures 6-53 to 6-55). Average concentrations during the monitoring period ranged from a low of 0.6 mg/L (Old River at Tracy Boulevard, Middle River at Tracy Boulevard, Middle River at Union Point, Grant Line Canal at Tracy Boulevard, and Doughty Cut at Grant Line Canal) to a high of 0.8 mg/L (Old River upstream of the ORT barrier). South Delta organic nitrogen concentrations in all 3 systems, Middle River, Old River and Grant Line Canal, fluctuated throughout the monitoring period with no discernible trends.

Orthophosphate

Phosphorus is essential to phytoplankton growth and can be a limiting nutrient for primary productivity. In cases where phosphate is a limiting factor, the discharge of raw or treated wastewater, agricultural drainage, and certain industrial wastes may stimulate the growth of photosynthetic microorganisms and macroorganisms in nuisance quantities. Orthophosphates applied to agricultural or residential cultivated land, as fertilizers, can be carried into surface water with storm runoff (American Public Health Association 2005).

Orthophosphate concentrations in the south Delta ranged from less than the reporting limit (0.01 mg/L) to 0.31 mg/L (Figures 6-53 to 6-55). Average concentrations during the monitoring period ranged from a low of 0.06 mg/L at Old River at head to a high of 0.17 mg/L at Old River upstream of the ORT barrier. South Delta orthophosphate concentrations fluctuated throughout the monitoring period with no discernible trends and tended to show minor variation between sites in Old River, Middle River, and Grant Line Canal. There was a slight peak at several of the sites during late June/early July, except at Old River near head, Middle River at Undine Road, and Middle River near Tracy Boulevard. Concentrations of organic nitrogen recorded at Old River at head were markedly lower in Old River from May through October.

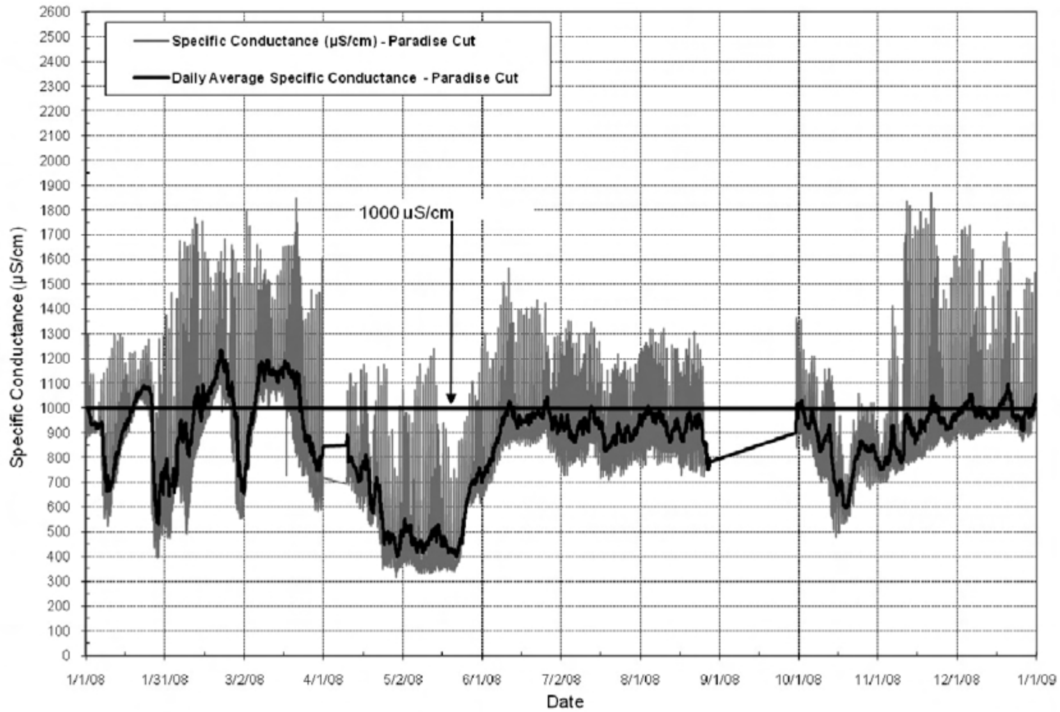
Discussion

A visual comparison of the 2008 water temperature plots for the south Delta monitoring sites revealed similar trends from site to site. This similarity is in part attributable to a common geographic location and similar meteorological conditions. Even though the sites are in a similar location, variations do occur from flow, tides, barrier operation, local discharges, and bathymetry.

Variation observed in specific conductance was due in part to differences in source water, flow dynamics, and agricultural pumping and return flows. Specific conductance values at Old River near head, Middle River at Undine Road, Doughty Cut above Grant Line Canal, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Boulevard showed similar trends in 2007, with the exception of a few conductance spikes at Middle River at Undine Road in January and February. The specific conductance patterns observed at the aforementioned sites are similar to those observed upstream in the San Joaquin River at Vernalis (Figure 6-3). Average daily specific conductance values rose and fell in 3 distinct periods from January through March, with the difference between the peaks and troughs being between 500 and 600 µS/cm, possibly as the result of increased flows in the San Joaquin River and flushing events during the same time periods. Values were typically lowest during the year at these locations from late April through early June, when flow was highest and specific conductance was lowest in San Joaquin River at Vernalis. Specific conductance values also decreased from late September through mid-October, when flow increased and specific conductance decreased in the San Joaquin River at Vernalis.

The Old River at Tracy Wildlife Association monitoring site is less than 0.25 mile downstream from Old River at Tracy Boulevard, which is a State Water Board–mandated compliance location for specific conductance during April through August (30-day running average not to exceed 700 µS/cm) and from September through March (30-day running average not to exceed 1,000 µS/cm). In June, July, and August, monthly average specific conductance values at Old River at Tracy Wildlife Association exceeded 700 µS/cm, and the average exceeded 1,000 µS/cm in December. Data analysis showed that Old River at Tracy Wildlife Association had significantly higher daily average specific conductance values in comparison to the other 3 Old River monitoring sites in June, July, and August. One possible explanation as to why specific conductance values are higher in the vicinity of Old River at Tracy Boulevard is the influence of Sugar Cut and Paradise Cut. DWR’s North Central Region Office Surface Water Data Section established stations in Paradise Cut and Sugar Cut to discern whether water in the area was higher in specific conductance than Old River at Tracy Boulevard and Old River at Tracy Wildlife Association. Figures 6-56 and 6-57 show a plot of Paradise Cut, Old River at Tracy Wildlife Association, and Sugar Cut specific conductance data. The preliminary data indicates that Paradise Cut and Sugar Cut are possible sources of high-conductivity water (values as high as 2,500 µS/cm) and under certain flow conditions may be contributing to the higher specific conductance values recorded downstream.

Figure 6-56. Paradise Cut and Old River at Tracy Wildlife Association specific conductance data (15-minute intervals)



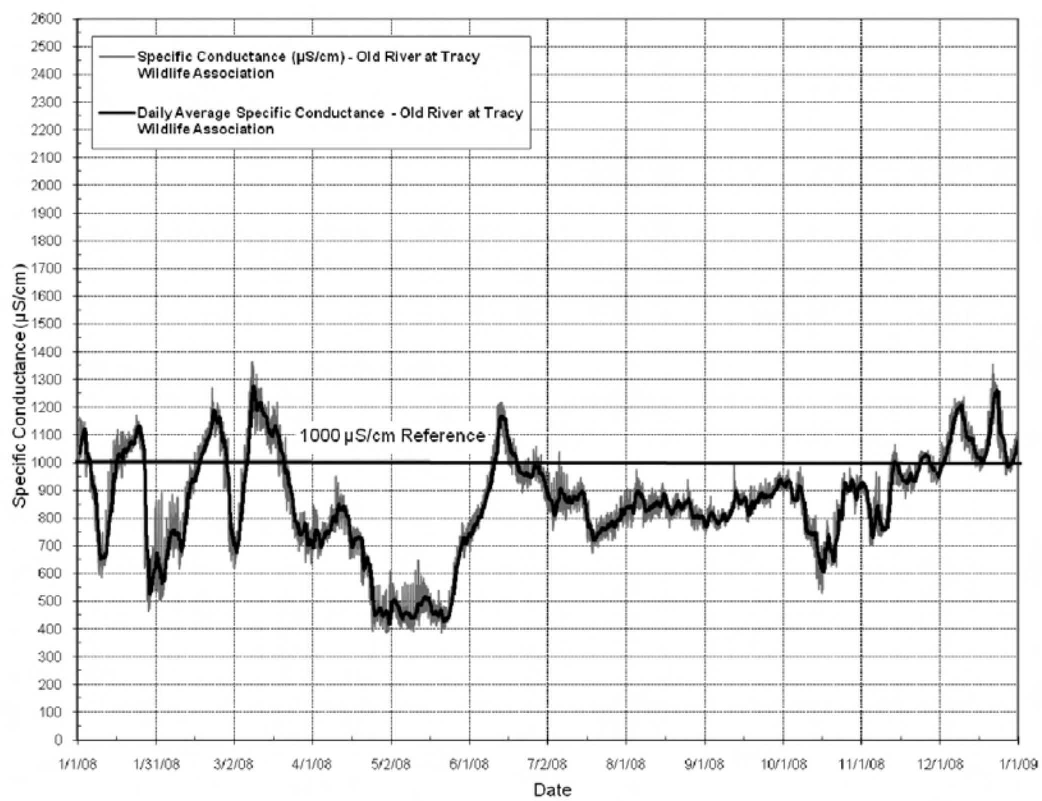
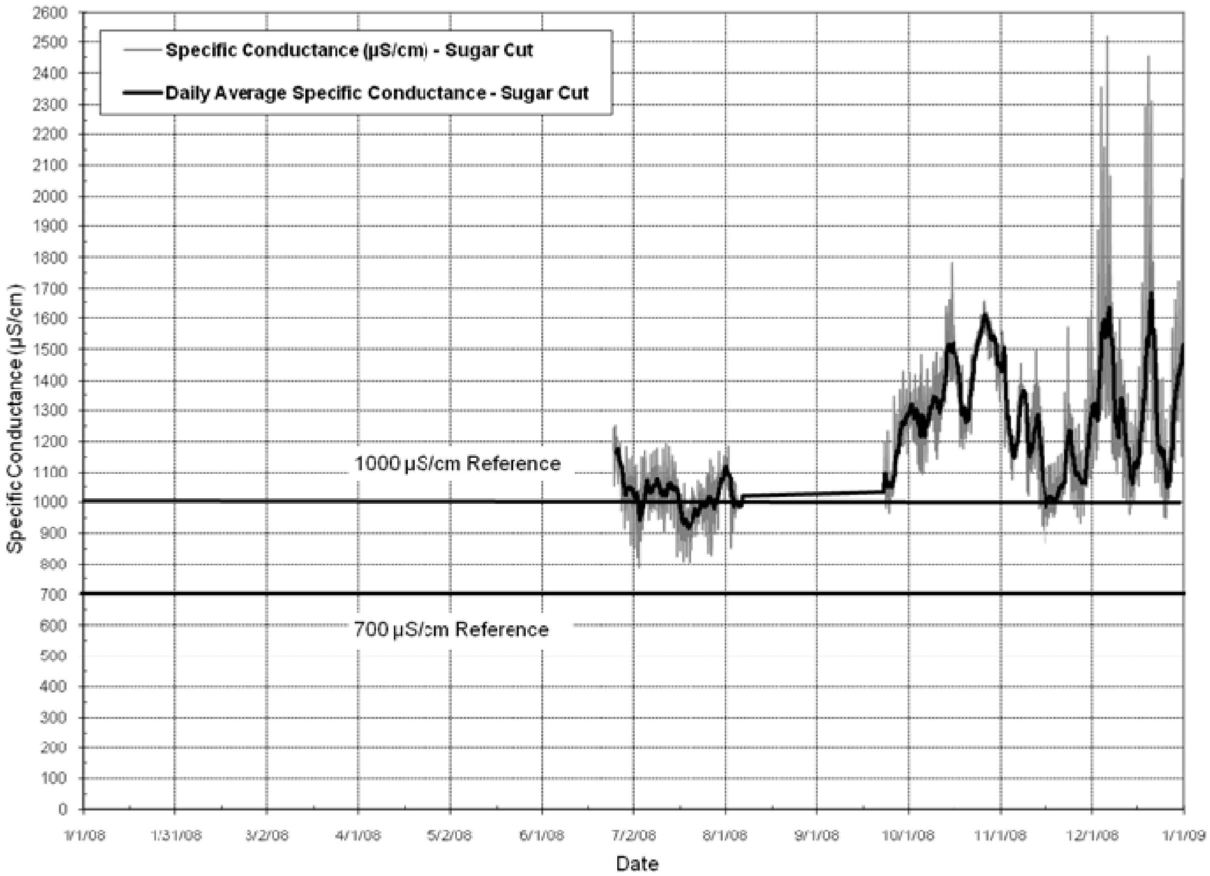


Figure 6-57. Sugar Cut specific conductance data (15-minute intervals)



Variation in specific conductance values was most pronounced at the stations upstream and downstream of the ORT barrier and at Grant Line Canal near Old River. These station locations represent areas where there was a marked difference between upstream and downstream specific conductance values. The higher-conductivity water measured on the ebb tide is likely from the San Joaquin River as well as other sources, and the lower-conductivity water measured on the flood tide likely consists of more Sacramento River water as well as other sources. Stations where there is likely more source water from the Sacramento River (Victoria Canal, Middle River at Union Point, and Middle River near Tracy Boulevard) had the lowest specific conductance values throughout the year, especially in July. Conductivity values at these sites were lowest in July, when there were increased CVP and SWP exports in comparison with May and June when exports were much lower. It is likely that specific conductance values at Victoria Canal, Middle River at Union Point, and Middle River near Tracy Boulevard increase when there is more net downstream flow in Old River, Middle River, and Grant Line Canal because the upstream water is higher in conductivity.

Specific conductance spikes were observed throughout most of the year at Middle River at Howard Road and are likely the result of agricultural pumping and returns flows, and flow dynamics. The fact that the observed conductivity spikes are greater in magnitude than the values recorded either upstream or downstream indicates that salts are introduced into the system in this area, though salt accumulation could also occur if there was little or no net downstream flow in the area. This area has lower specific conductance values than Middle River at Undine Road, indicating that less saline water is reaching this location during flood tides. The higher-conductivity water measured on the ebb tide is likely from the San

Joaquin River as well as other sources, and the lower-conductivity water measured on the flood tide likely consists of more Sacramento River water as well as other sources.

Algal biomass was highest in the spring and summer (as indicated by chlorophyll *a* concentrations), likely as the result of warm water temperatures, low flow conditions, and the availability of nutrients. In the spring (late March through early May) high concentrations of chlorophyll *a* were observed at all the Old River and Grant Line Canal monitoring stations and at Middle River at Undine Road. High chlorophyll *a* concentrations in the summer (early June through late August) were observed at Old River near head, Old River at Tracy Wildlife Association, Middle River at Undine Road, and all the Grant Line Canal monitoring stations, except Grant Line Canal near Old River. The sites with likely more source water from the Sacramento River (Victoria Canal, Middle River at Union Point, and Middle River near Tracy Boulevard) had low chlorophyll *a* concentrations throughout most of the year.

During the late spring through early fall, there was distinct diurnal variation in DO concentrations at stations with high chlorophyll *a* (algae) concentrations, such as Old River near head and Middle River at Undine Road. Diurnal variation in DO concentrations occurs via algal and plant photosynthesis and respiration. During a typical summer day, DO concentrations reached a maximum in the late afternoon and a minimum during the early morning.

The majority of the DO concentrations below 5.0 mg/L were recorded during the summer (June–August) when water temperatures were highest. The stations that had the most daily average DO concentrations below 5 mg/L were Middle River at Howard Road, Grant Line Canal above the GLC barrier, and Grant Line Canal at Tracy Boulevard. The primary causes of low DO concentrations at these stations during the summer are likely high biological oxygen demand (oxygen consumption by microorganisms) due to organic waste (algal biomass, detritus, etc.), high summer water temperatures (decreased DO saturation), and low flow conditions.

The upstream monitoring sites (Old River near head and Middle River at Undine Road) had no daily average DO readings below 5.0 mg/L, likely because these locations had the highest estimated algal biomass. The supersaturated conditions observed at these sites kept the average daily DO concentrations above 5.0 mg/L. DO concentrations at the downstream sites (Victoria Canal, Middle River at Union Point, and Middle River near Tracy Boulevard) were likely influenced predominantly by water temperature. These sites had lower average DO concentrations in the summer, when water temperatures were warm, but had zero average daily DO reading below 5.0 mg/L.

pH values were highest during the summer when water temperatures were warm and there were high chlorophyll *a* concentrations measured at these sites. Most of the observed pH concentrations greater than 9.0 were recorded at 3 locations: Old River near head, Middle River at Undine Road, and Grant Line Canal above the GLC barrier. The high pH values observed at these locations are likely a direct function of algal photosynthesis; as algae consume carbon dioxide (CO_2) from water, they produce DO as a byproduct of photosynthesis. Less CO_2 in the water drives the pH higher (decrease in carbonic acid), which results in the water becoming more alkaline or the pH becoming higher. Downstream stations with the least algae biomass, such as Victoria Canal, Middle River at Union Point, and Middle River at Howard Road had zero pH values greater than 9.0.

In general, turbidity at all 13 sites was lower in fall and higher during the winter and summer. Turbidity readings during the summer were higher because of increased primary productivity (algae biomass), low San Joaquin River flows, and agricultural pumping and return flows. Two storm-related turbidity events can be observed at most of the stations, especially at the Grant Line Canal stations in mid-January and late January/early February. The farthest sites downstream (Victoria Canal, Middle River at Union Point, and Grant Line Canal near Old River) had the lowest turbidity readings during most of the year. High water clarity at these sites during the late spring through early fall may be attributed in part to lower algae biomass.

Victoria Canal was established as a compliance monitoring station for turbidity in 2007 to protect Delta smelt. In 2008, there were 43 days where the daily mean turbidity value was greater than 12.0 NTU. The majority of these occurrences (39) were in the winter. For more information on compliance monitoring for Delta smelt, contact Jared Frantzich at jfrantzi@water.ca.gov.

Conclusion and Recommendations

Data collected in 2008 elucidated trends in water temperature, DO, pH, specific conductance, turbidity, and chlorophyll *a* in the south Delta. Further research on the dynamic conditions and variables influencing these constituents will need to be done before any definitive conclusions can be made, however some trends are becoming apparent. The areas near the GLC barrier and at Middle River at Howard Road had the lowest DO concentrations in 2008, with numerous average daily DO values in the summer below 5.0 mg/L. Additional monitoring and analysis are necessary to determine the relationships between DO concentrations and factors such as algae biomass, biological oxygen demand, and flow. Specific conductivity at Old River at Tracy Wildlife Association was the highest throughout most of the year in the south Delta. Data from the new specific conductivity monitoring stations on Sugar Cut and Paradise Cut will be analyzed to help understand the influences on the Old River at Tracy Wildlife Association and Old River at Tracy Boulevard stations. Monitoring will continue in 2009 at all 13 stations to supplement the existing time-series record, provide historical data, and meet the requirements outlined in the CWA Section 401 water quality certification for the TBP.

Data sets for this program should be reviewed in connection with the Integrated Risk Information System (IRIS). Data that has been quality assured and quality controlled could be made available via a geographic information system (GIS) Web interface that would make the data more accessible and meaningful to interested parties.

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Chapter 7. Hydrodynamic Modeling

This chapter presents the simulation of historical 2008 Delta hydrodynamic conditions and the effect of the installation and operation of the south Delta temporary barriers. For this analysis, historical Delta inflows, consumptive use, and exports were simulated under 2 barrier conditions:

1. Historical 2008 installation and operation of the temporary barriers.
2. No installation of south Delta temporary barriers.

DSM2 (Hydro module) was used to simulate the Delta hydrodynamics. This model is a 1-dimensional open-channel unsteady flow model based on a 4-point finite difference solution of equations of momentum and continuity. The model network extends north to Sacramento River at I Street, south to San Joaquin River at Vernalis, and west to Martinez, where the observed 15-minute time series governs how the tide signal propagates into the Delta.

2008 Delta Boundary Conditions

Flow and stage information required at model boundaries were downloaded from the CDEC Web site (http://cdec.water.ca.gov). Input data were visually examined before any simulation. Any gaps or errors in data were of short duration, and values were estimated via simple interpolation. The resulting boundary conditions for the 2008 simulation are shown in Figures 7-1 through 7-4.

Figure 7-1. Daily average historical inflow from the Sacramento River, 2008

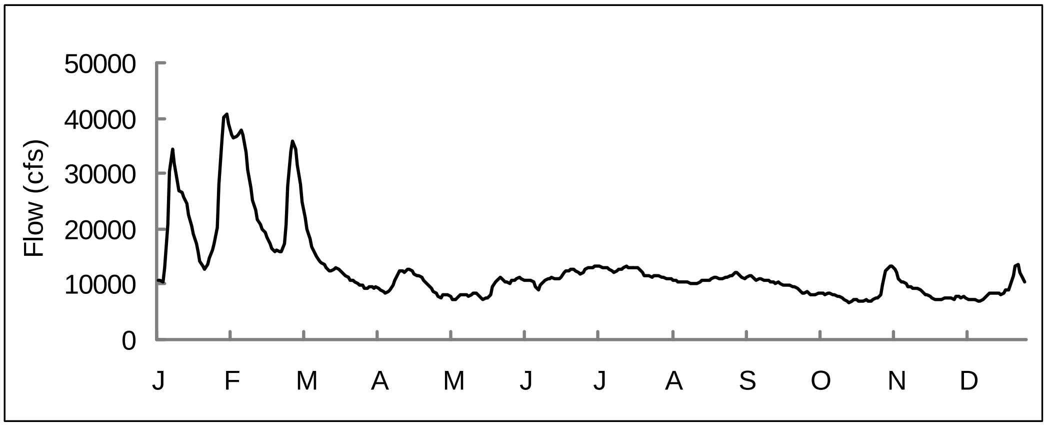


Figure 7-2. Daily average historical inflow from the Yolo Bypass, 2008

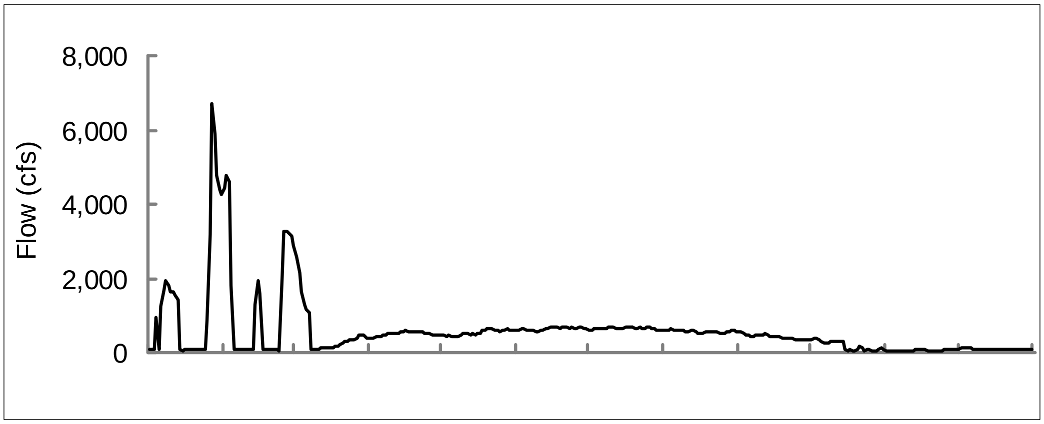


Figure 7-3. Daily average historical inflow from the San Joaquin River, 2008

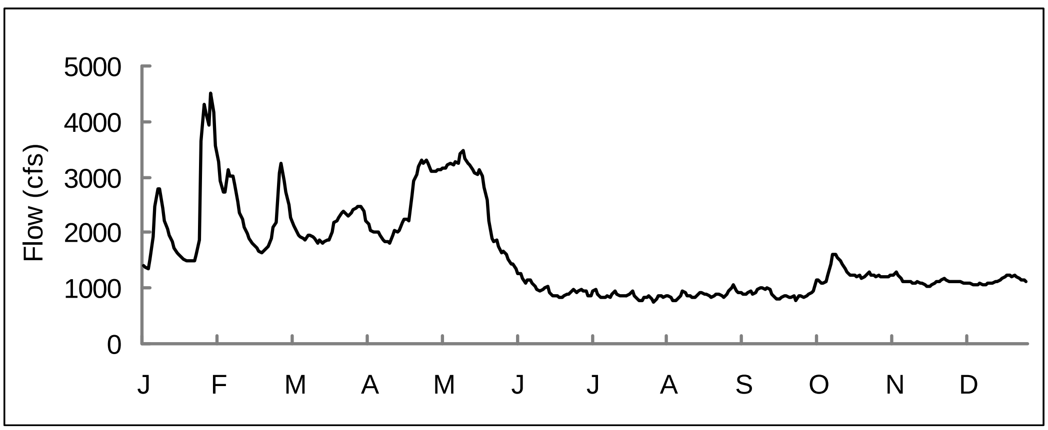
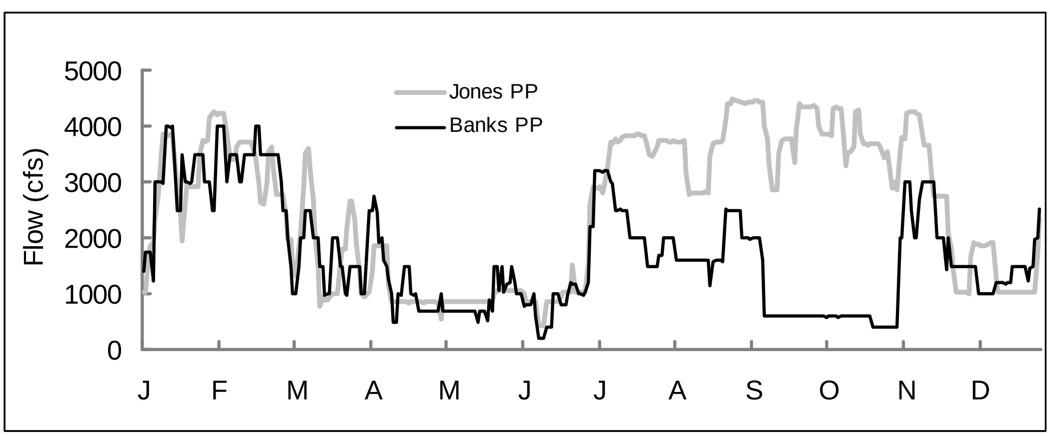


Figure 7-4. Daily average historical pumping at Banks and Jones Pumping Plants, 2008



2008 Delta Consumptive Use

The Delta Island Consumptive Use (DICU) model provided an estimate of the amount of water diverted from and returned to Delta channels due to agricultural activities. Input to the DICU model includes precipitation, pan evaporation data, and water year type. The water year type determines which of 2 possible cropping patterns in the Delta is assumed. Delta land use in turn contributes to the estimation of agricultural water needs.

South Delta Structures

All 3 temporary agricultural barriers were installed in 2008. The HORB was only installed in the fall. The DSM2 simulation timed the installation and removal of the barriers to the changes in actual observed stages, which indicated effective closure or opening of the channel.

Table 7-1 lists the historical installation and removal of the south Delta barriers. The GLC barrier is typically installed in 2 stages. The first stage installs the boat ramp but leaves the center of the channel open. The second stage closes the channel. The date and time shown in Table 7-1 for the GLC barrier refers to the second phase installation because this is the time when significant changes in stage upstream due to this barrier are first evident. Flap gates in the barrier culverts were at times tied open or allowed to operate tidally. This level of detail of operation, while incorporated in the historical simulation, is not shown in Table 7-1.

Table 7-1. Historical south Delta temporary barriers installation and removal, 2008

	Installation			Removal		
Barrier	Started[a] (2008)	Ended[a] (2008)	DSM2 simulation date, time (2008)	Started[a] (2008)	Ended[a] (2008)	DSM2 simulation date, time (2008)
MR barrier	May 21	May 21	May 25, 1700	Nov 5	Nov 5	Nov 5, 1600
ORT barrier	Jun 4	Jun 4	Jun 4, 1500	Nov 4	Nov 4	Nov 3, 1200
GLC barrier	Jun 26	Jun 26	Jun 26, 0800	Nov 11	Nov 11	Nov 10, 1100
Spring HORB	–	–	–	–	–	–
Fall HORB	Oct 16	Oct 16	Oct 16, 0800	Nov 3	Nov 3	Nov 3, 0800

[a] As reported by DWR’s TBP.

Delta Downstream Stage at Martinez

The downstream boundary of DSM2 is Martinez, where a time series of observed historical 15-minute data from 2008 was used for the simulation.

Delta Cross Channel Operation

The Delta Cross Channel gates were operated in 2008 and modeled in the historical DSM2 simulation as shown in Table 7-2.

Table 7-2. Historical Delta cross channel operation for 2008

Date	Time	Operation	Date	Time	Operation
Dec 14, 2007	1000	Close	Nov 22, 2008	0800	Open
May 23, 2008	0900	Open	Nov 22, 2008	1545	Close
May 27, 2008	0900	Close	Nov 23, 2008	0800	Open
May 30, 2008	0900	Open	Nov 23, 2008	1545	Close
Jun 2, 2008	0900	Close	Nov 24, 2008	0800	Open
Jun 6, 2008	0900	Open	Nov 24, 2008	1545	Close
Jun 9, 2008	0900	Close	Nov 25, 2008	0800	Open
Jun 13, 2008	0900	Open	Nov 25, 2008	1545	Close
Nov 10, 2008	0700	Half open	Nov 26, 2008	0800	Open
Nov 12, 2008	0800	Open	Dec 13, 2008	1545	Close
Nov 12, 2008	1545	Close	Dec 14, 2008	0825	Open
Nov 13, 2008	0800	Open	Dec 14, 2008	1545	Close
Nov 13, 2008	1545	Close	Dec 15, 2008	0825	Open
Nov 14, 2008	0800	Open	Dec 15, 2008	1545	Close
Nov 14, 2008	1545	Close	Dec 16, 2008	0825	Open
Nov 15, 2008	0800	Open	Dec 16, 2008	1545	Close
Nov 15, 2008	1545	Close	Dec 17, 2008	0825	Open
Nov 16, 2008	0800	Open	Dec 17, 2008	1545	Close
Nov 16, 2008	1545	Close	Dec 18, 2008	0825	Open
Nov 17, 2008	0800	Open	Dec 18, 2008	1545	Close
Nov 17, 2008	1545	Close	Dec 19, 2008	0825	Open
Nov 18, 2008	0800	Open	Dec 19, 2008	1545	Close
Nov 18, 2008	1545	Close	Dec 20, 2008	0825	Open
Nov 19, 2008	0800	Open	Dec 20, 2008	1545	Close
Nov 19, 2008	1545	Close	Dec 21, 2008	0825	Open
Nov 20, 2008	0800	Open	Dec 21, 2008	1545	Close
Nov 20, 2008	1545	Close	Dec 22, 2008	0825	Open
Nov 21, 2008	0800	Open	Dec 22, 2008	1545	Close
Nov 21, 2008	1545	Close			

Validation of DSM2 Simulation of Historical 2008 Delta Hydrodynamics

Delta hydrodynamics were simulated according to the conditions presented above. Stage and flow results of the DSM2 simulation of historical Delta hydrodynamics were compared with available observed data (Figure 7-5). Figure 7-6 presents observed and simulated daily minimum and maximum stage, and Figure 7-7 presents observed and simulated daily minimum, maximum, and average flow.

Figure 7-5. Locations where DSM2-simulated and measured stages and flows are presented, 2008

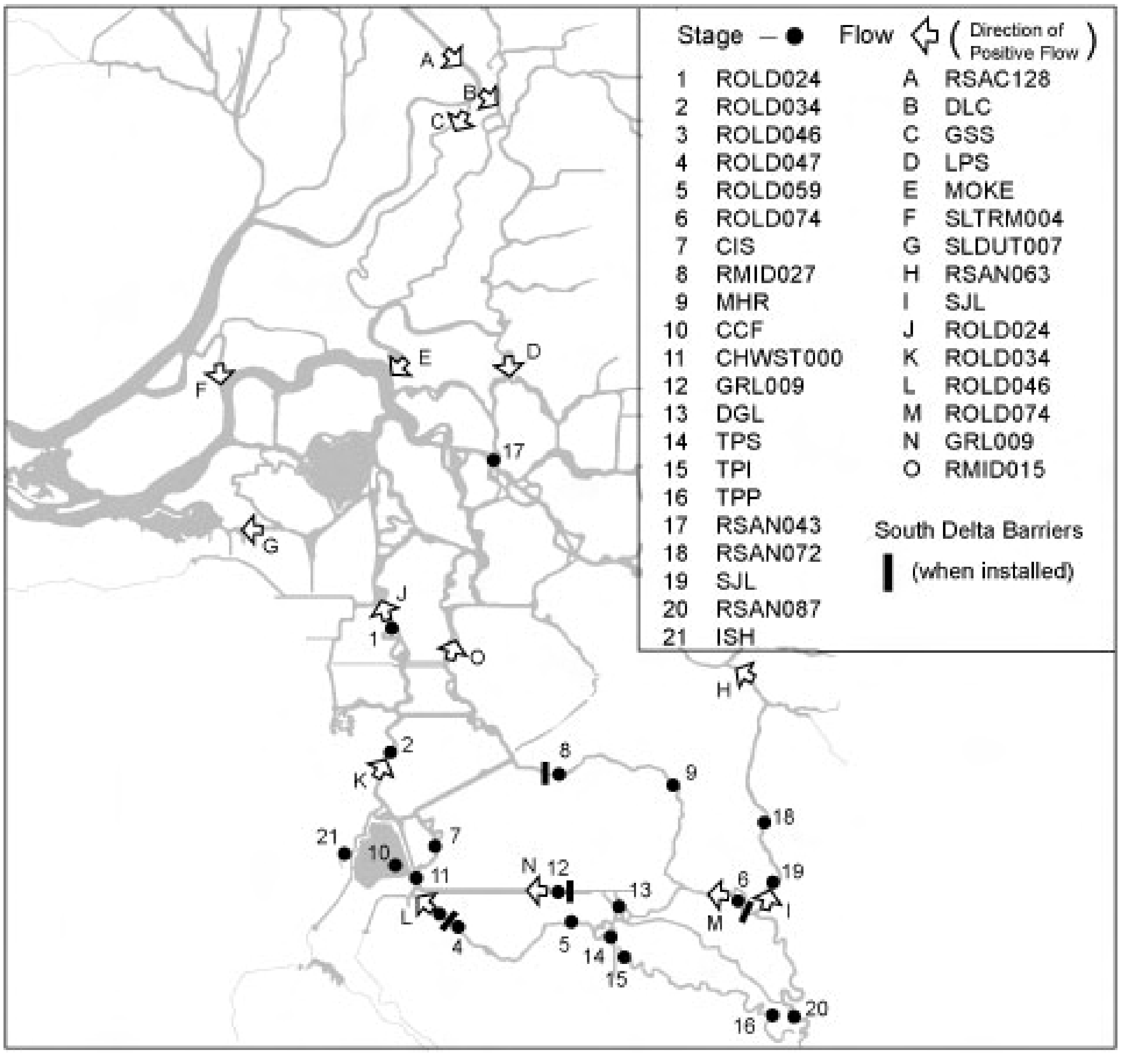


Figure 7-6 indicates that the DSM2 simulation reproduces the observed effect the temporary agriculture barriers have on upstream minimum (see stations RMID027, MHR, DGL, ROLD047, ROLD059, and TPS). Simulated daily levels generally match observed values well, with the exceptions of stages in Clifton Court Forebay (CCF) and TPS. Model errors at these locations have been noted before and appear to occur for most DSM2 historical simulations.

Figure 7-6. Comparison of DSM2-simulated and observed daily stage, 2008

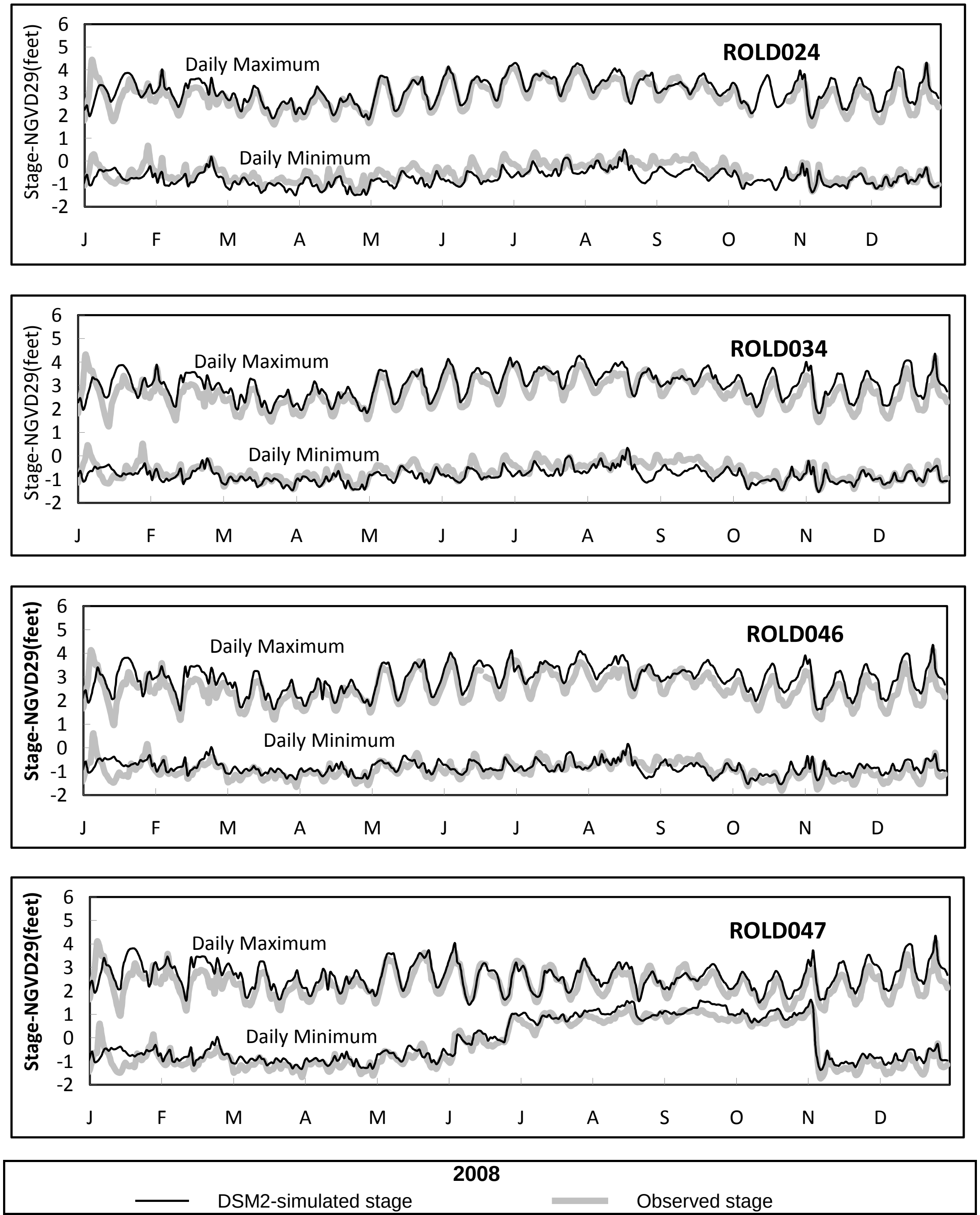


Figure 7-6 (cont.). Comparison of DSM2-simulated and observed daily stage, 2008

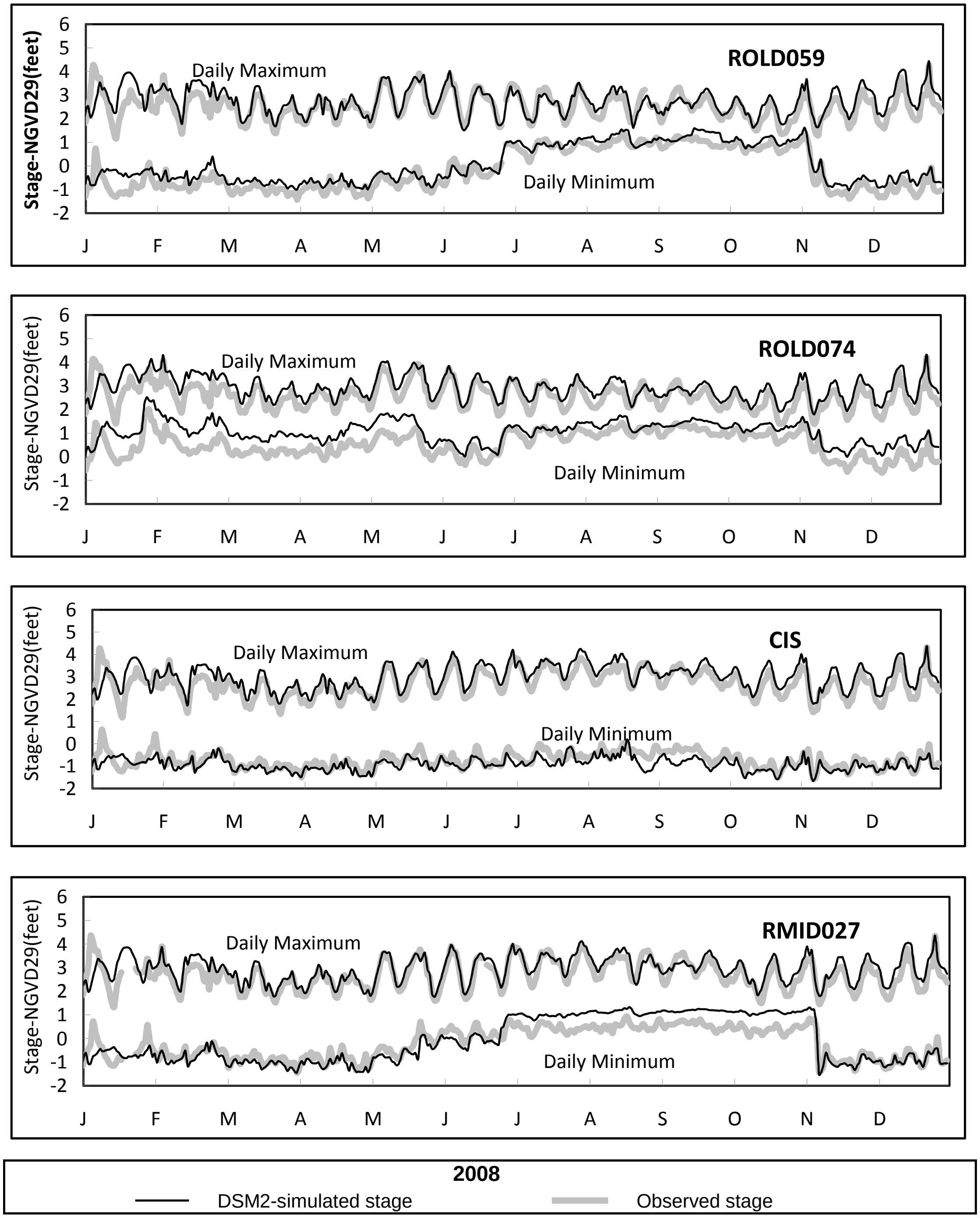


Figure 7-6 (cont.). Comparison of DSM2-simulated and observed daily stage, 2008

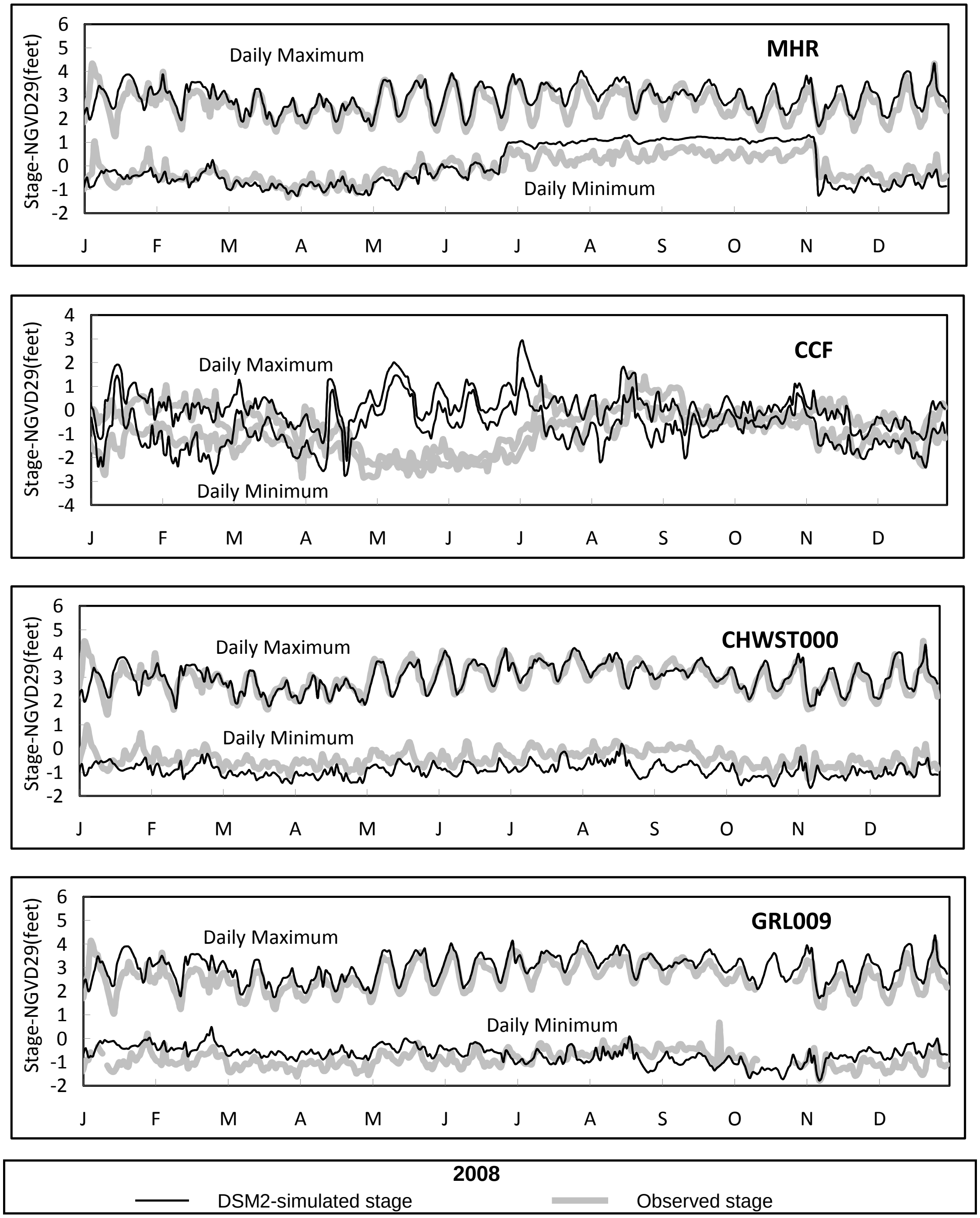


Figure 7-6 (cont.). Comparison of DSM2-simulated and measured daily stage, 2008

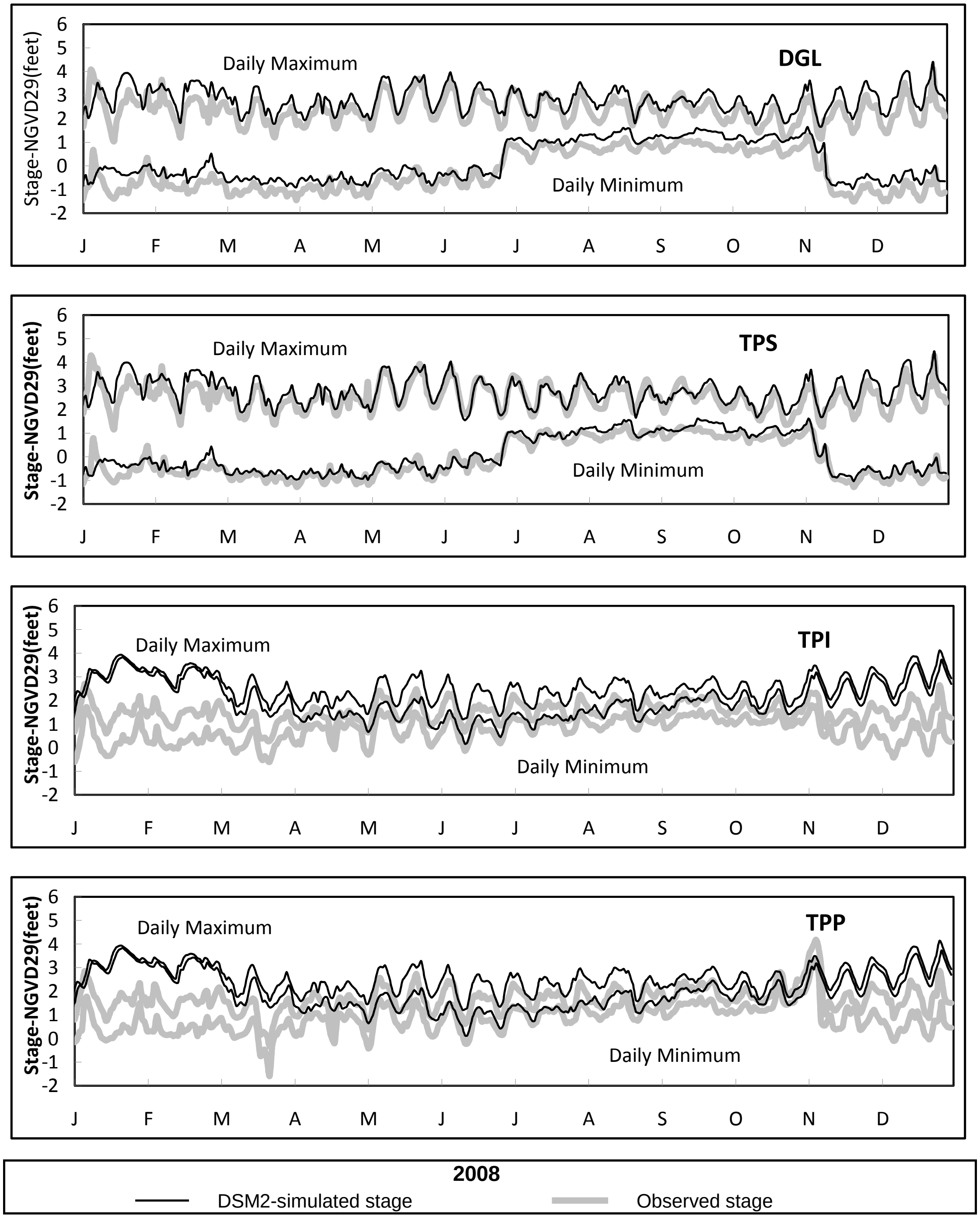


Figure 7-6 (cont.). Comparison of DSM2-simulated and measured daily stage, 2008

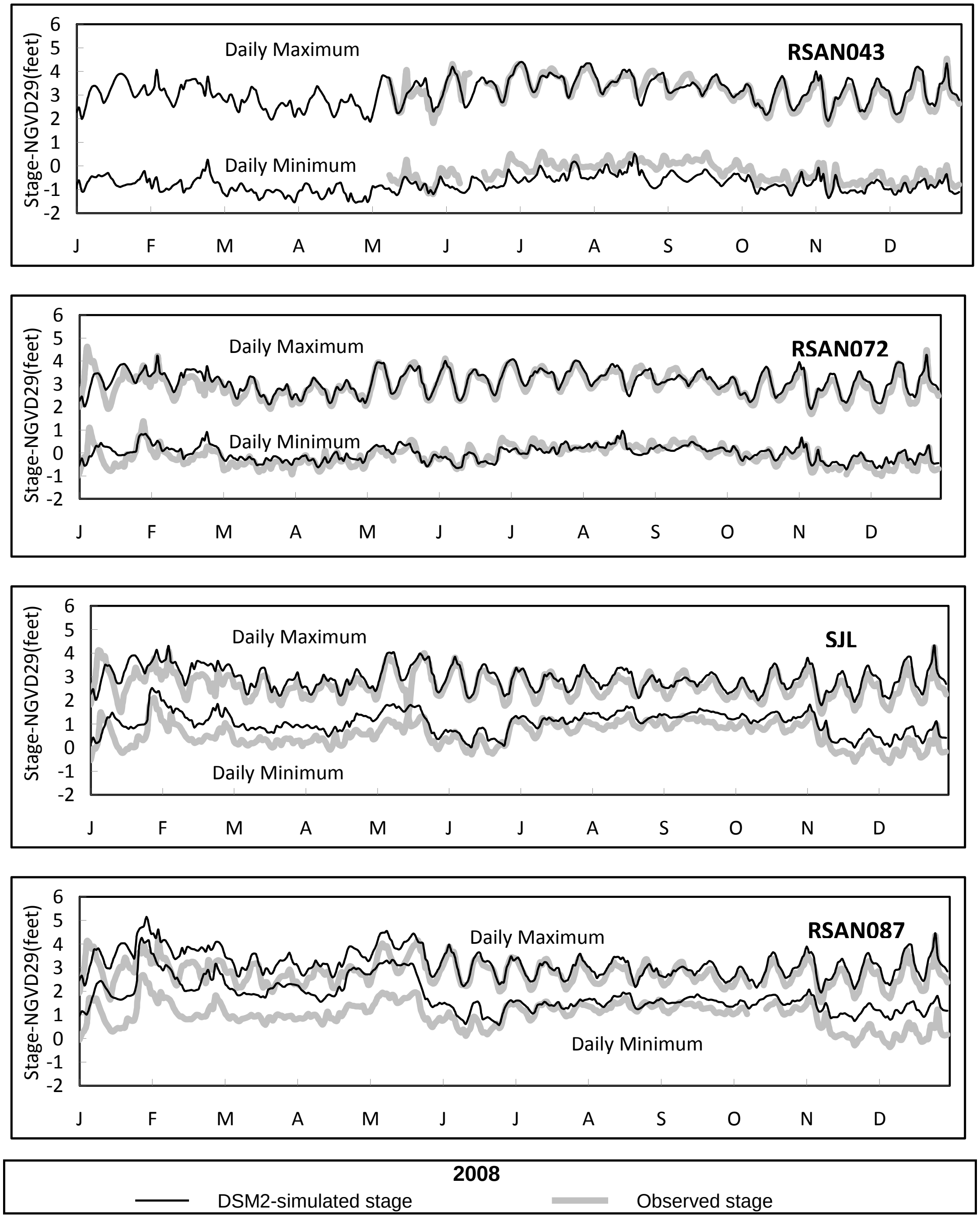


Figure 7-6 (cont.). Comparison of DSM2-simulated and measured daily stage, 2008

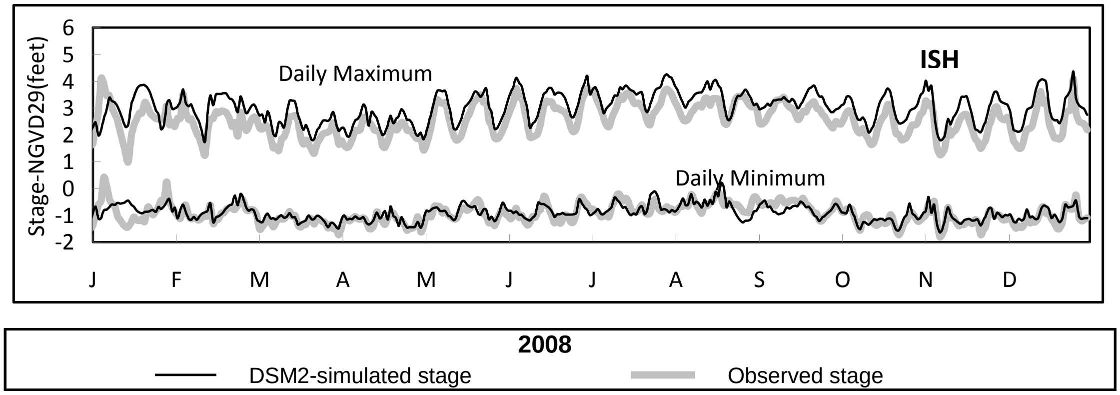


Figure 7-7 shows DSM2-simulated and observed daily maximum, average, and minimum flow wherever measured flow data is available in the Delta for 2008. The DSM2 simulation matched observed peak and average flows well at almost all locations in the Delta outside of the area affected by the temporary barriers in the south Delta. Locations where flow was measured and that are within the influence of the barriers are Old River downstream of the ORT barrier (ROLD046), Old River at head (ROLD074), and Grant Line Canal downstream of the GLC barrier site (GRL009). All 3 of these locations are actually downstream of the temporary barrier site, but flow at ROLD074 can be assumed to be influenced by the installation of the ORT and GLC temporary barriers.

At ROLD046, ROLD074, and GRL009, the simulated daily average flow matches the observed daily average flow well. At ROLD046, observed peak upstream flows were near zero while DSM2 simulated peak upstream flows of approximately 1,000 cfs. Peak downstream flows matched better once the GLC barrier was installed, otherwise the DSM2 simulation showed peak downstream flows that were less than those observed. At ROLD074, simulated peak upstream and downstream flows matched observed flows well. Changes in tidal flow here in response to temporary barrier installation in Old River and Grant Line Canal are evident in both observed and simulated flows. At GRL009, although the observed and simulated daily average flows match well, the observed daily peak upstream and downstream flows can significantly exceed simulated flows. This pattern has been noted in other years and may reflect the currently assumed Grant Line Canal bathymetry used in DSM2.

Together, Figures 7-6 and 7-7 indicate that the DSM2 simulations of historical 2008 Delta conditions with and without barrier installation should provide meaningful results with which to evaluate how the barriers affected water levels and circulation in the south Delta.

Figure 7-7. Comparison of DSM2-simulated and measured daily flow, 2008

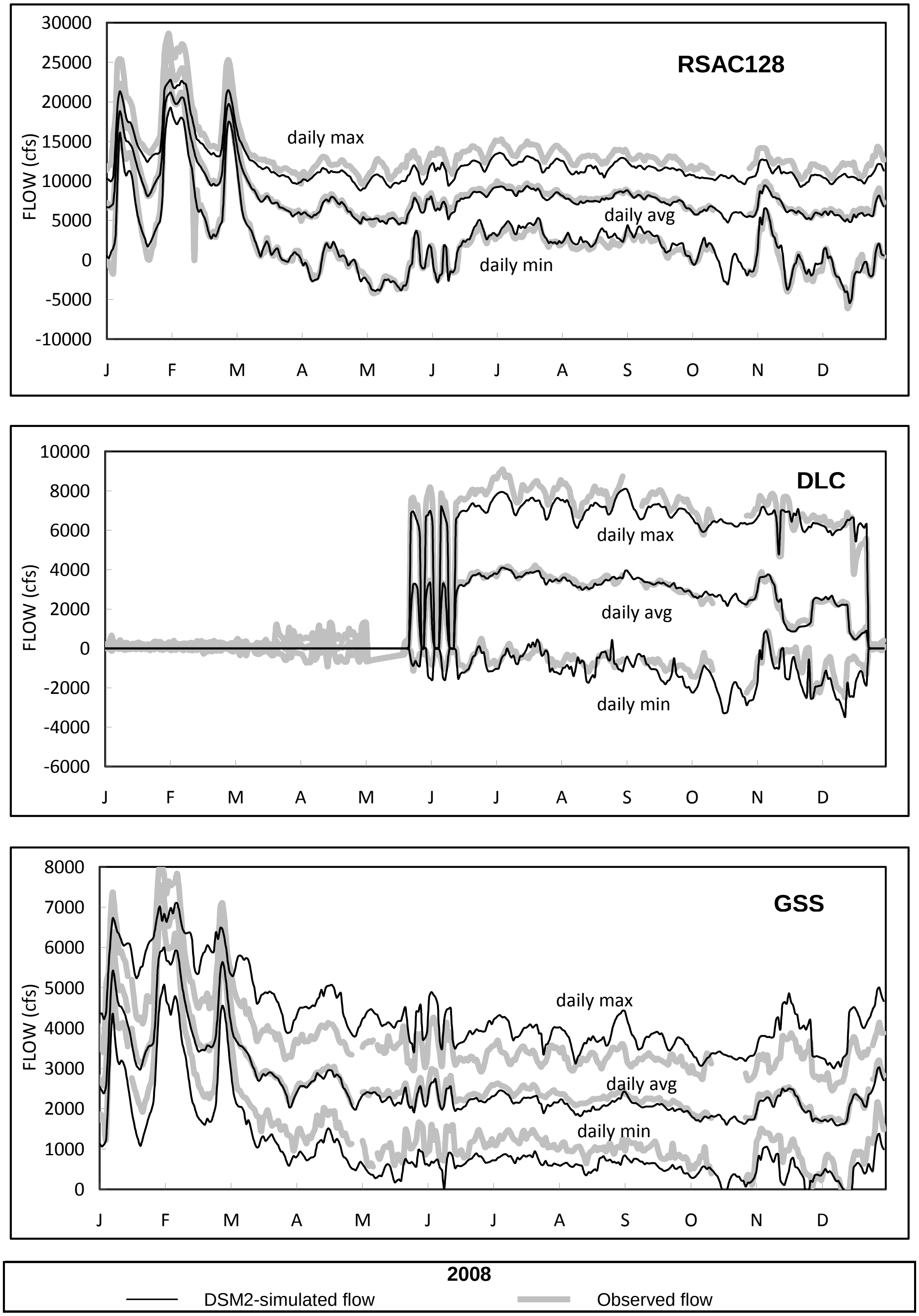


Figure 7-7 (cont.). Comparison of DSM2-simulated and measured daily flow, 2008

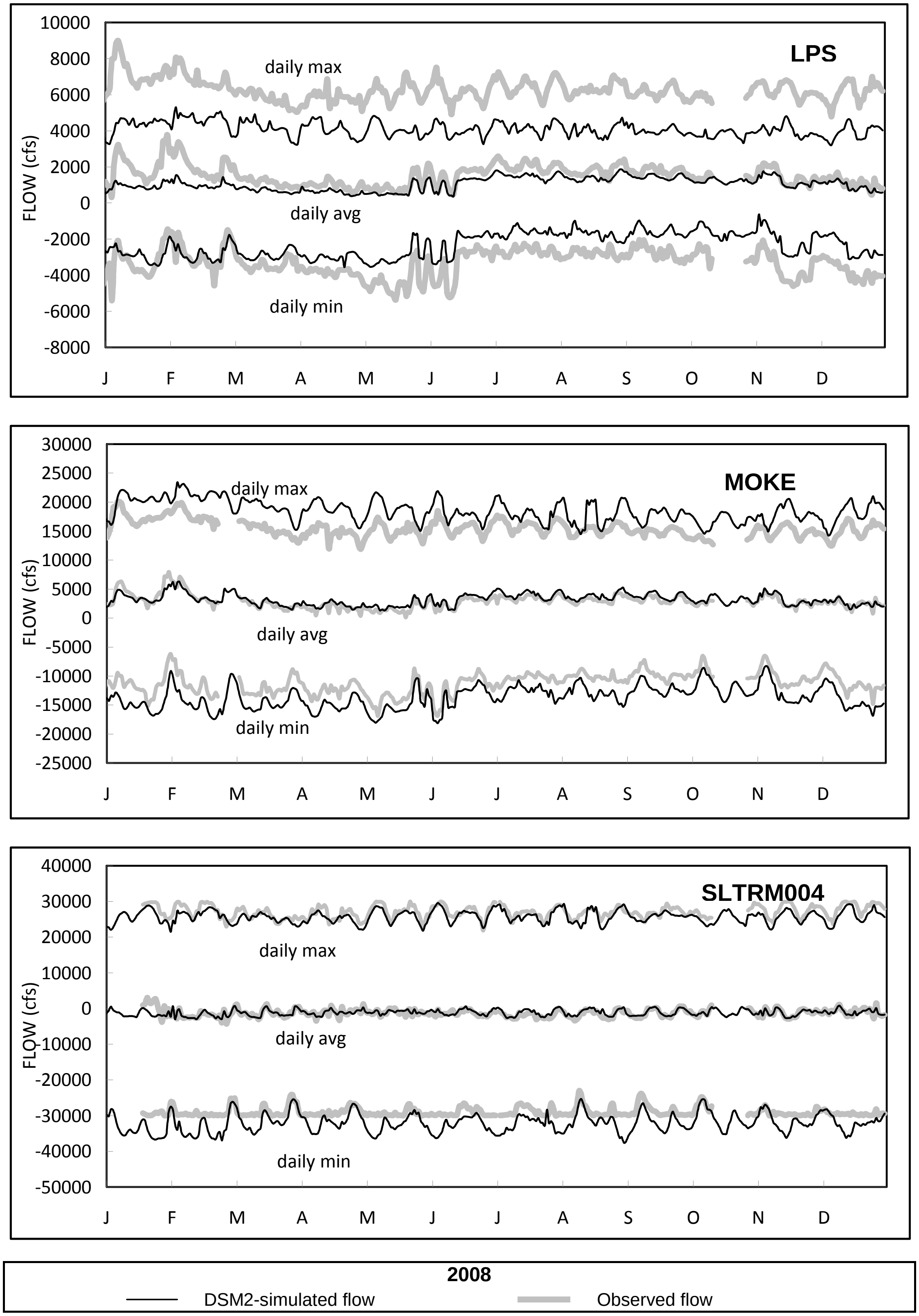


Figure 7-7 (cont.). Comparison of DSM2-simulated and measured daily flow, 2008

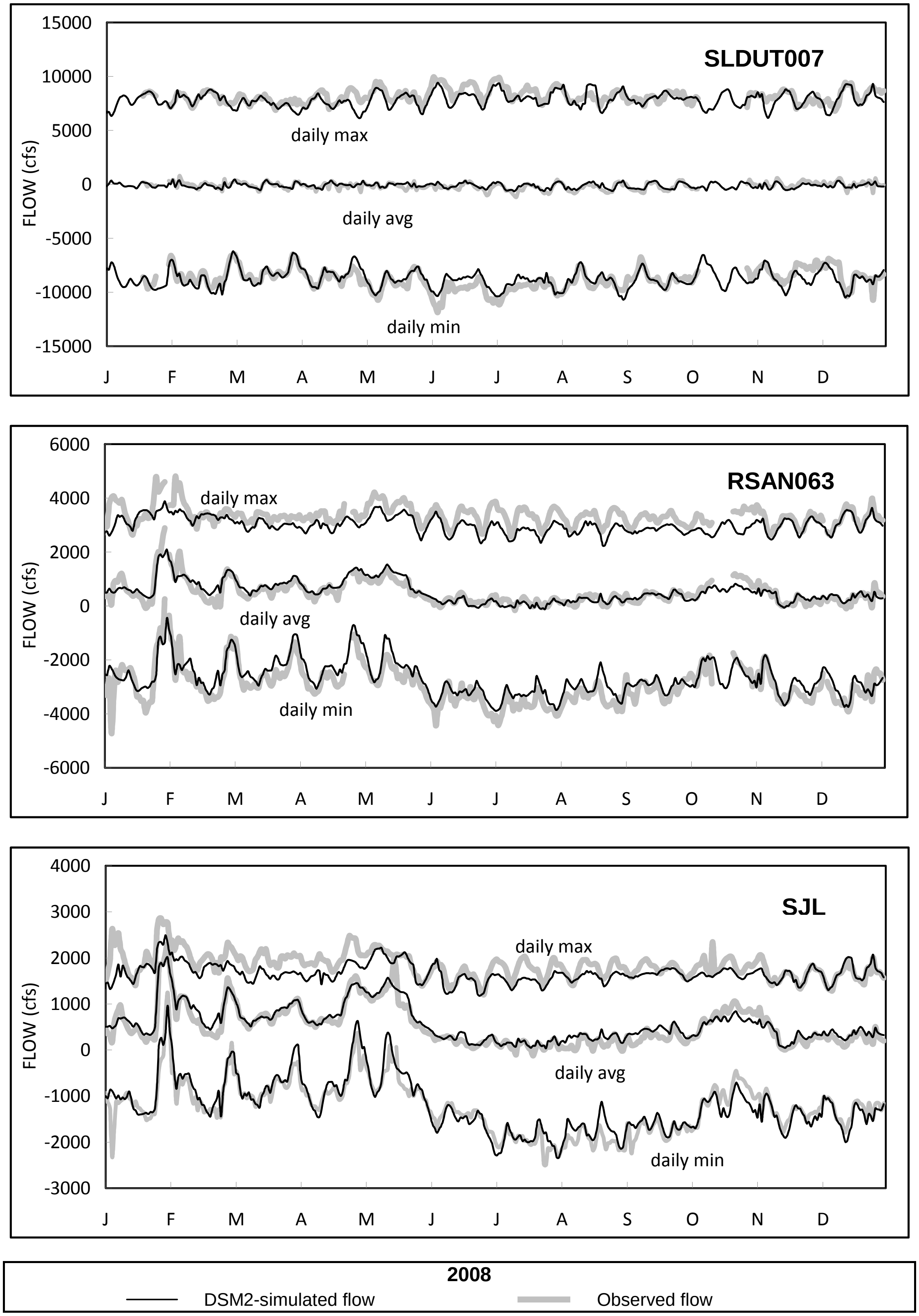


Figure 7-7 (cont.). Comparison of DSM2-simulated and measured daily flow, 2008

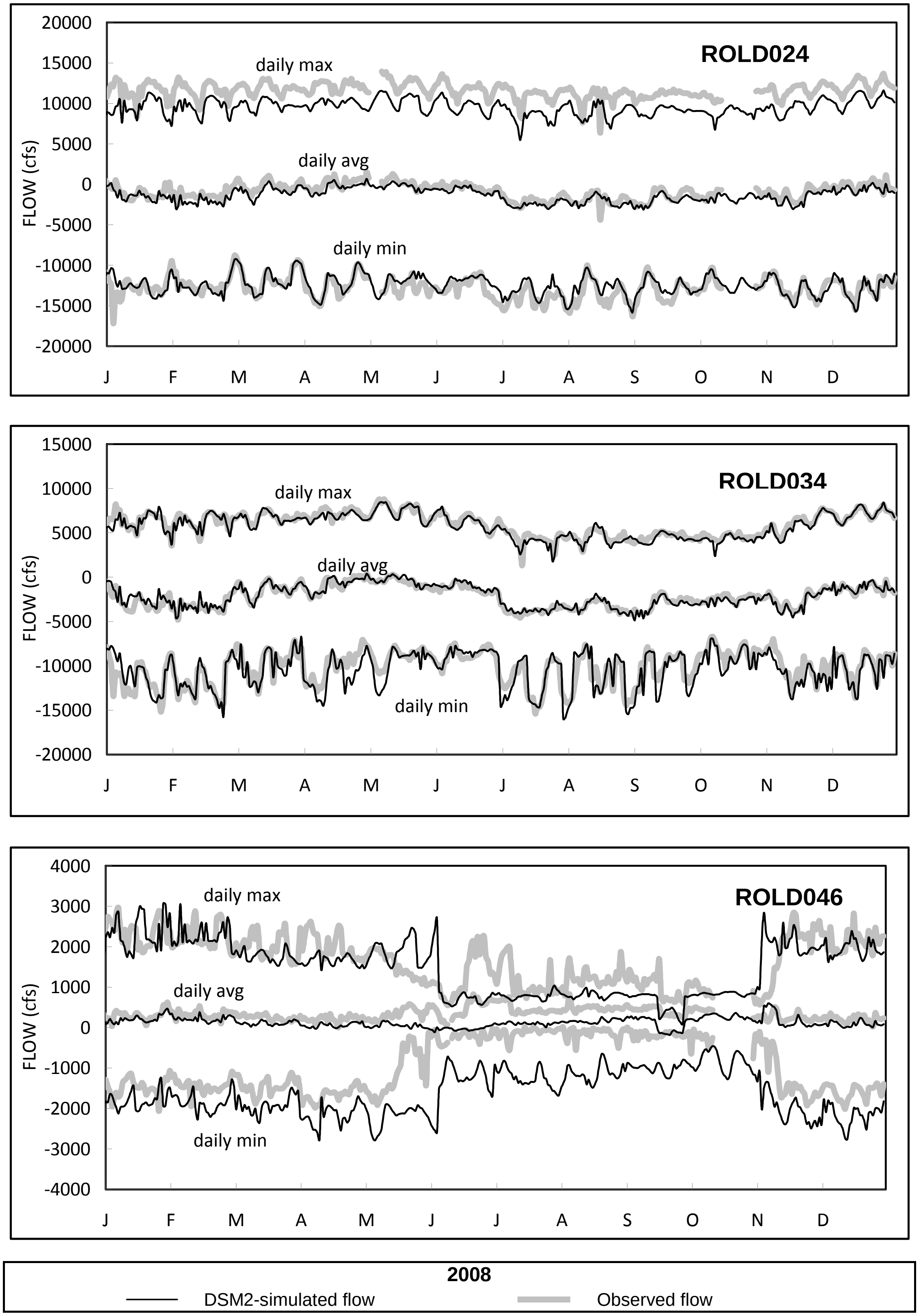
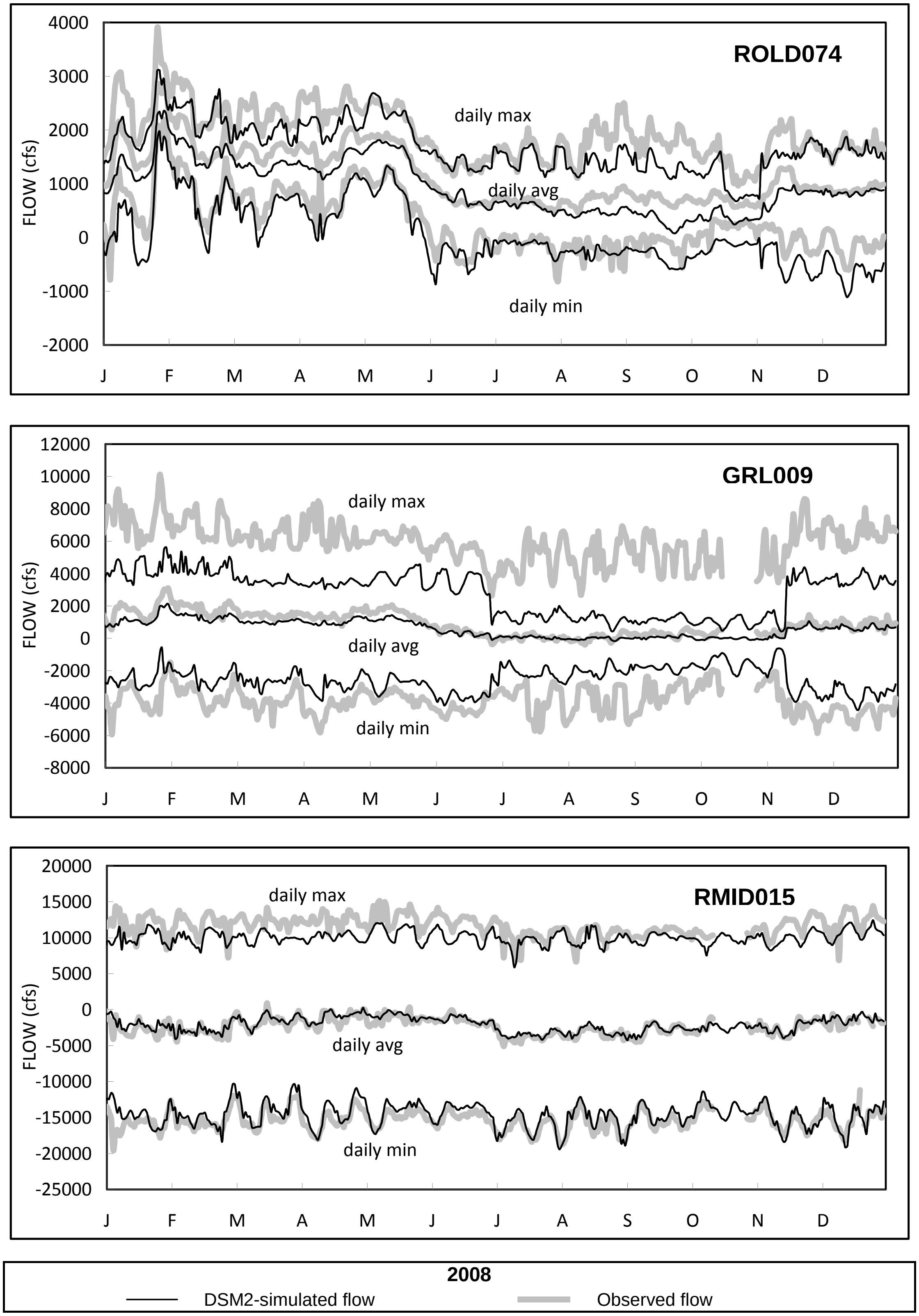


Figure 7-7 (cont.). Comparison of DSM2-simulated and measured daily flow, 2008



Effect of Temporary Barriers' Installation and Operation on South Delta Hydrodynamics

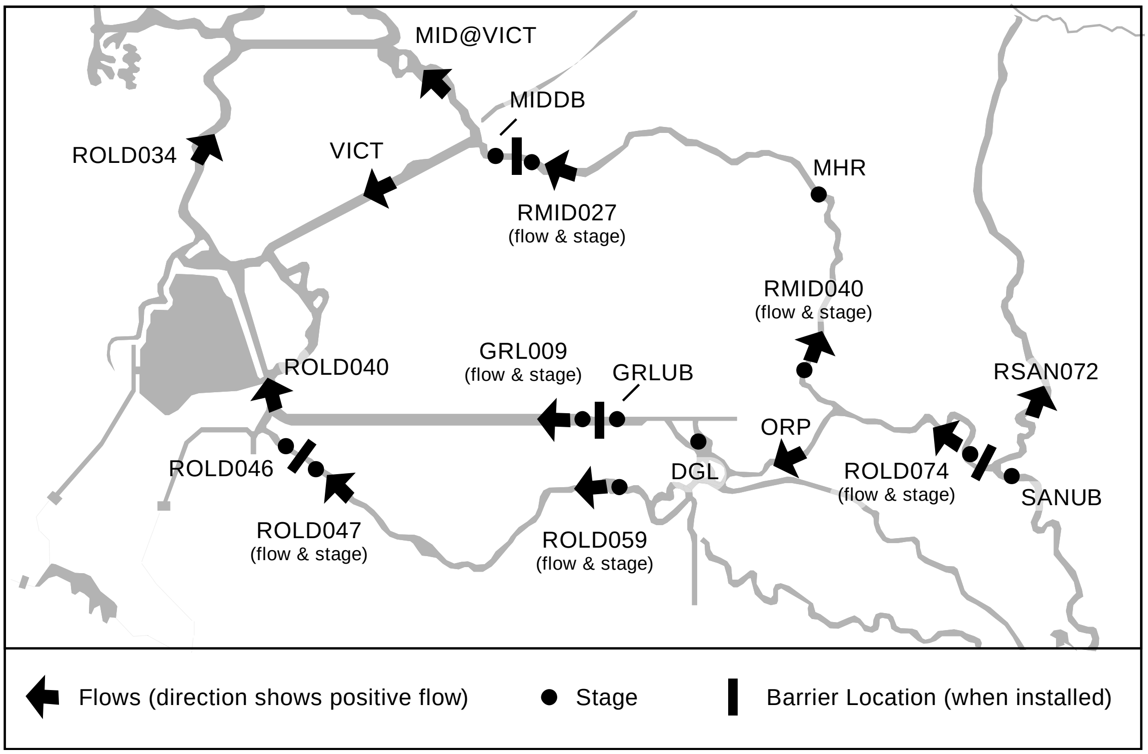
In order to better process the 2008 Delta hydrodynamics, DSM2 simulation results were separated into 19 periods for which significant Delta inflows and exports were fairly constant and basic south Delta barrier configurations were unchanging. The 19 periods and their characteristics are shown in the table below. The Delta hydrodynamics, as modeled by DSM2, are presented for each of the periods (2008), excluding these periods when barriers were in the process of installation or removal: June 1–4, June 27–30, October 16, and November 1–11. Operational changes to the temporary barriers of having flap gates tied open or operated tidally were not factored into the processing of the simulation results. The GLC barrier was not considered installed until the middle of the channel was closed, so the period of June 5–26 is presented as only the ORT and MR barriers being installed.

Table 7-3. Characteristics of time intervals for presentation of simulation results, 2008

Period (2008)	Period average flows				Period barrier status (in place or out)			
	Sacramento River and Yolo Bypass (cfs)	San Joaquin River (cfs)	Delta Mendota Canal pumping (cfs)	SWP pumping (cfs)	MR	ORT	GLC	HORB
Jan 1–5	11,159	1,351	1,302	1,441	--	--	--	--
Jan 6–21	23,556	1,772	2,835	2,190	--	--	--	--
Jan 22–31	25,604	3,138	3,235	2,906	--	--	--	--
Feb 1–4	47,854	3,176	4,174	3,971	--	--	--	--
Feb 5–13	31,263	2,773	3,575	3,325	--	--	--	--
Feb 14–29	22,263	2,274	2,827	3,448	--	--	--	--
Mar 1–31	14,710	2,179	1,813	1,594	--	--	--	--
Apr 1–30	10,733	2,356	1,080	1,237	--	--	--	--
May 1–20	8,688	3,167	825	632	--	--	--	--
May 21–31	11,088	2,023	999	1,073	IN	--	--	--
Jun 5–26	11812	984	884	756	IN	IN	--	--
Jul 1–31	13,216	903	3,406	2,127	IN	IN	IN	--
Aug 1–31	11,457	860	3,428	1,733	IN	IN	IN	--
Sept 1–30	10,976	812	3,942	1,052	IN	IN	IN --	
Oct 1–15	8,445	935	3,950	571	IN	IN	IN	--
Oct 17–31	7,442	1,034	3,686	485	IN	IN	IN	IN
Nov 12–19	9,917	1,037	3,572	2,805	--	--	--	--
Nov 20–30	8,028	1,173	1,992	1,777	--	--	--	--
Dec 1–31	8,785	1,193	1,314	1,315	--	--	--	--

Hourly simulated stage and flow data for each period were used to generate data for box plots, which graphically show period minimum, maximum, 25% quartile, 75% quartile, and median values. By the usual sign convention, negative flow values correspond to upstream flow. The locations where box plots of stage and flow are presented are shown in Figure 7-8, with arrows indicating assumed positive flow direction. Tables containing the numerical values associated with the box plots are presented at the end of this report (Appendix B).

Figure 7-8. Locations where simulated Delta stages and flows for analysis of 2008 conditions are presented



Shown in Figures 7-9 and 7-10 are the box plots of simulated stages and flow for time periods when at least 1 barrier was historically installed. Stages are presented upstream and downstream of each barrier location, and flows are presented throughout the south Delta in order to convey the general circulation patterns. Distributions of flow and stage from both the historical simulation and the condition of no barriers assumed installed are provided to help analyze the effect of the installation of the barriers.

Figure 7-11 graphically presents the effects of the temporary barriers in 2008 on flow circulation and minimum water levels in the south Delta under the same time periods presented in Figures 7-9 and 7-10.

Discussion

The installation of the temporary barriers in 2008 significantly altered stages and flows in the south Delta. When the MR barrier was installed in May, minimum water levels immediately upstream of the barrier were raised approximately 0.5 foot. This improvement decreased moving upstream until it essentially was eliminated at the junction of Old River. Thus, the effects on water levels due to the installation of the MR barrier alone were essentially limited to Middle River. The installation of the ORT barrier at the beginning of June in 2008 raised minimum water levels immediately upstream of the barrier approximately 0.5 foot, an effect that decreased farther upstream. The ORT barrier had little effect on water levels in Middle River or Grant Line Canal. For the period of June 5 to June 26, 2008, only the

MR and ORT barriers were fully installed. During this time, these barriers' primary impact was significantly raising water levels immediately upstream, an effect which diminished farther upstream until becoming negligible in Grant Line Canal. The overall circulation pattern in the south Delta during this period was only modestly altered by the 2 barriers because the flow split from the San Joaquin River down the head of Old River and the subsequent flow down Grant Line Canal weren't strongly affected.

The complete installation of the GLC barrier in the beginning of July raised the minimum water level in Grant Line Canal upstream of the barrier approximately 1.5 feet and raised levels in Middle River and Old River an additional 1 foot and 0.5 foot respectively. Also, circulation patterns were altered, as shown by a reduced portion of San Joaquin River flow down the head of Old River and less of a portion of this water then passing down Grant Line Canal and more going down Old River. Thus, the full impact on minimum water levels and changed flow patterns was not realized until the GLC barrier was completely installed.

In general, the installation of the temporary barriers also resulted in reduced tidal variation in flows near the barriers, a trend once again made more pronounced in Old River and Middle River with the installation of the GLC barrier. Each of the barriers still allowed some downstream flow, while both upstream and downstream flow was suppressed in the channels upstream of each barrier site.

The installation of the notched HORB in October significantly further reduced the amount of San Joaquin River flowing down Old River and Grant Line Canal.

Figure 7-9. Distribution of DSM2-simulated stages for historical 2008 conditions with and without temporary barriers installed

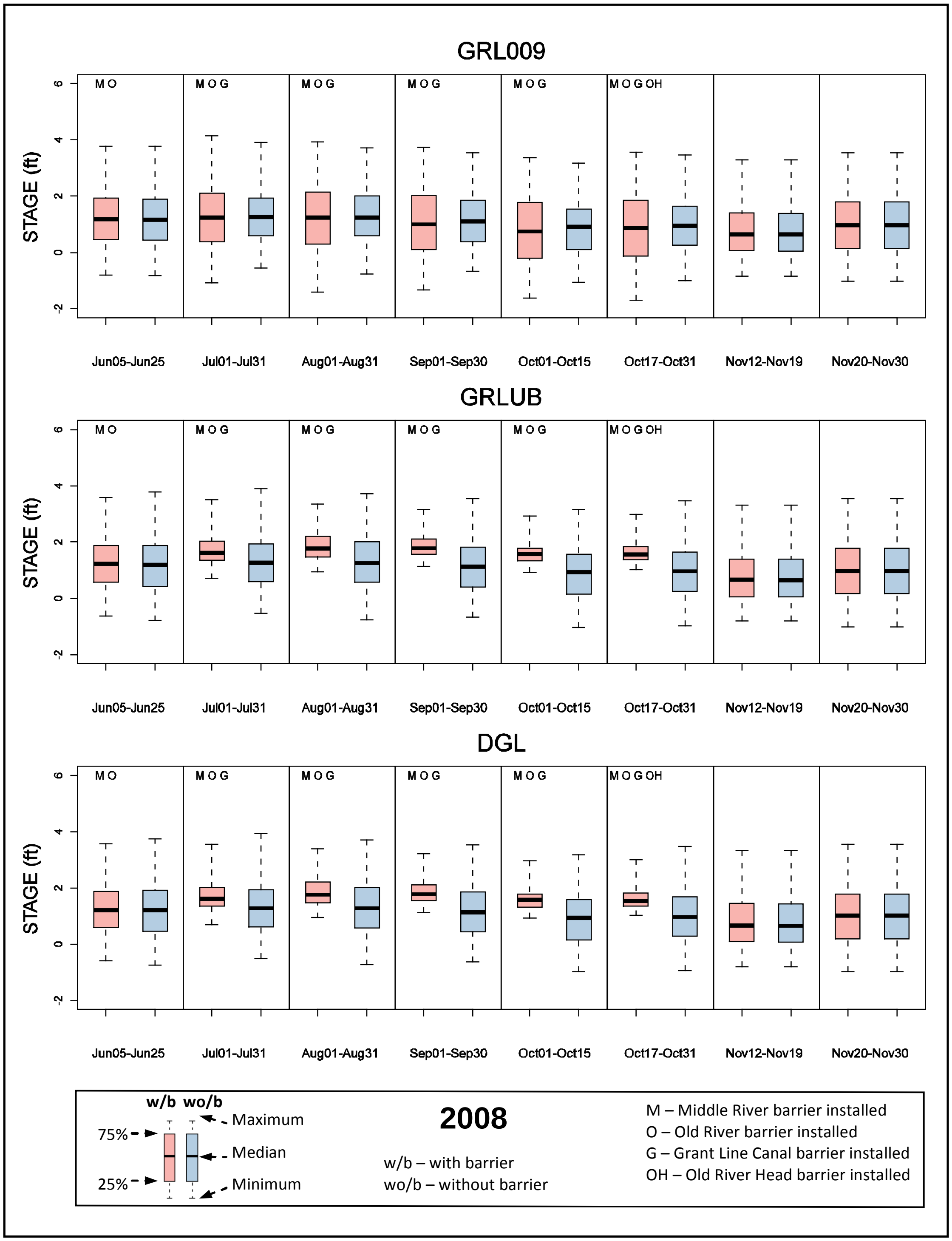


Figure 7-9 (cont.). Distribution of DSM2-simulated stages for historical 2008 conditions with and without temporary barriers installed

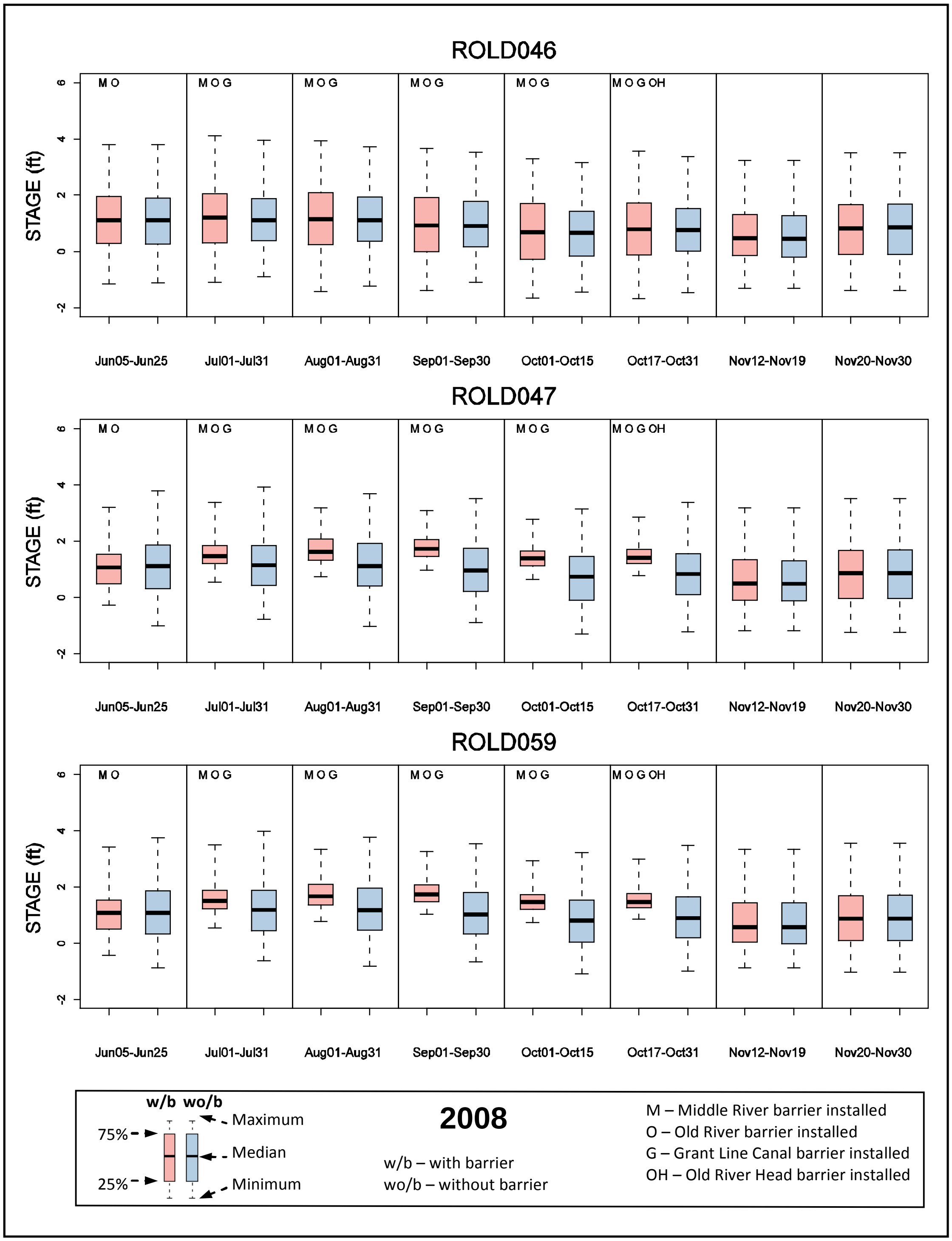


Figure 7-9 (cont.). Distribution of DSM2-simulated stages for historical 2008 conditions with and without temporary barriers installed

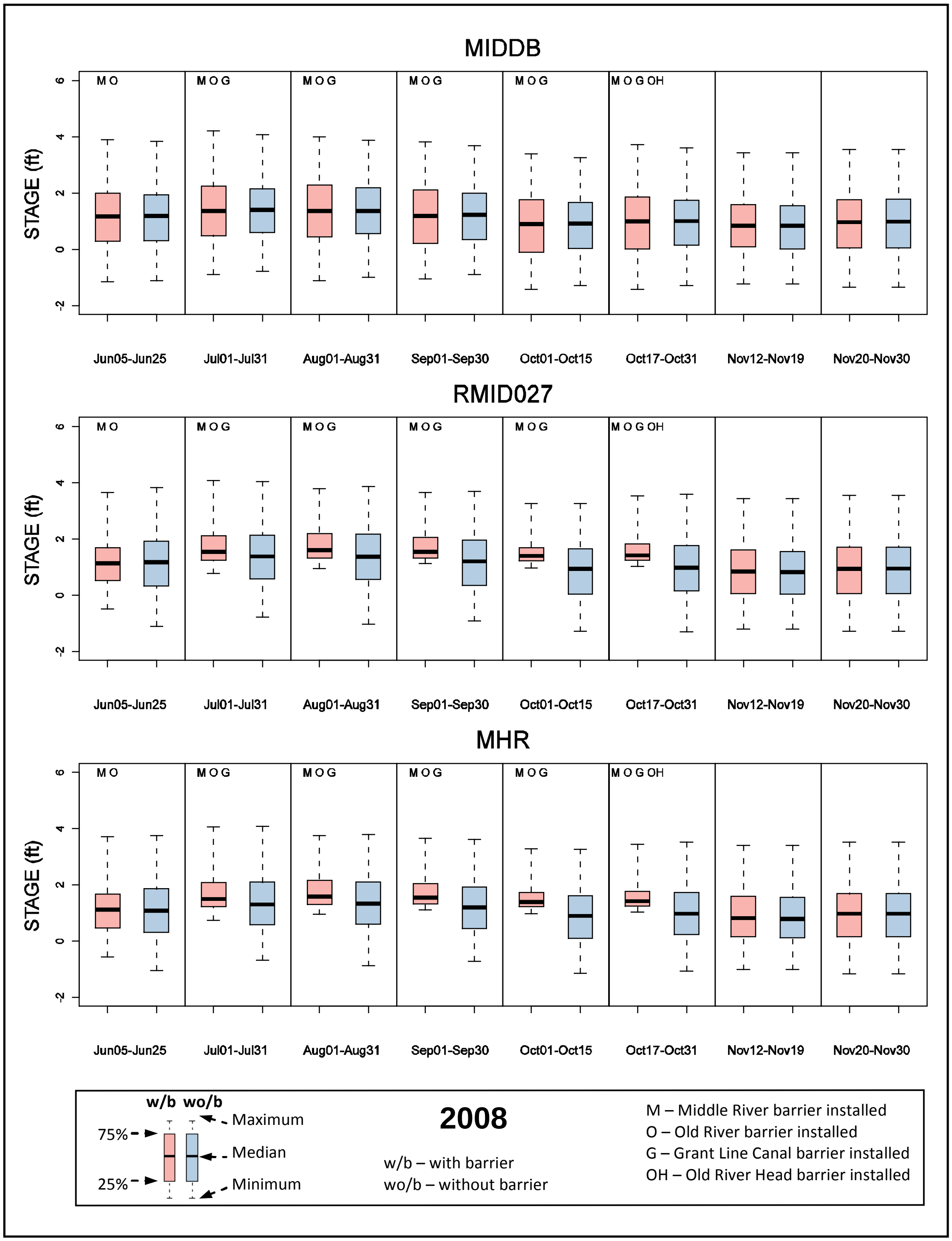


Figure 7-9 (cont.). Distribution of DSM2-simulated stages for historical 2008 conditions with and without temporary barriers installed

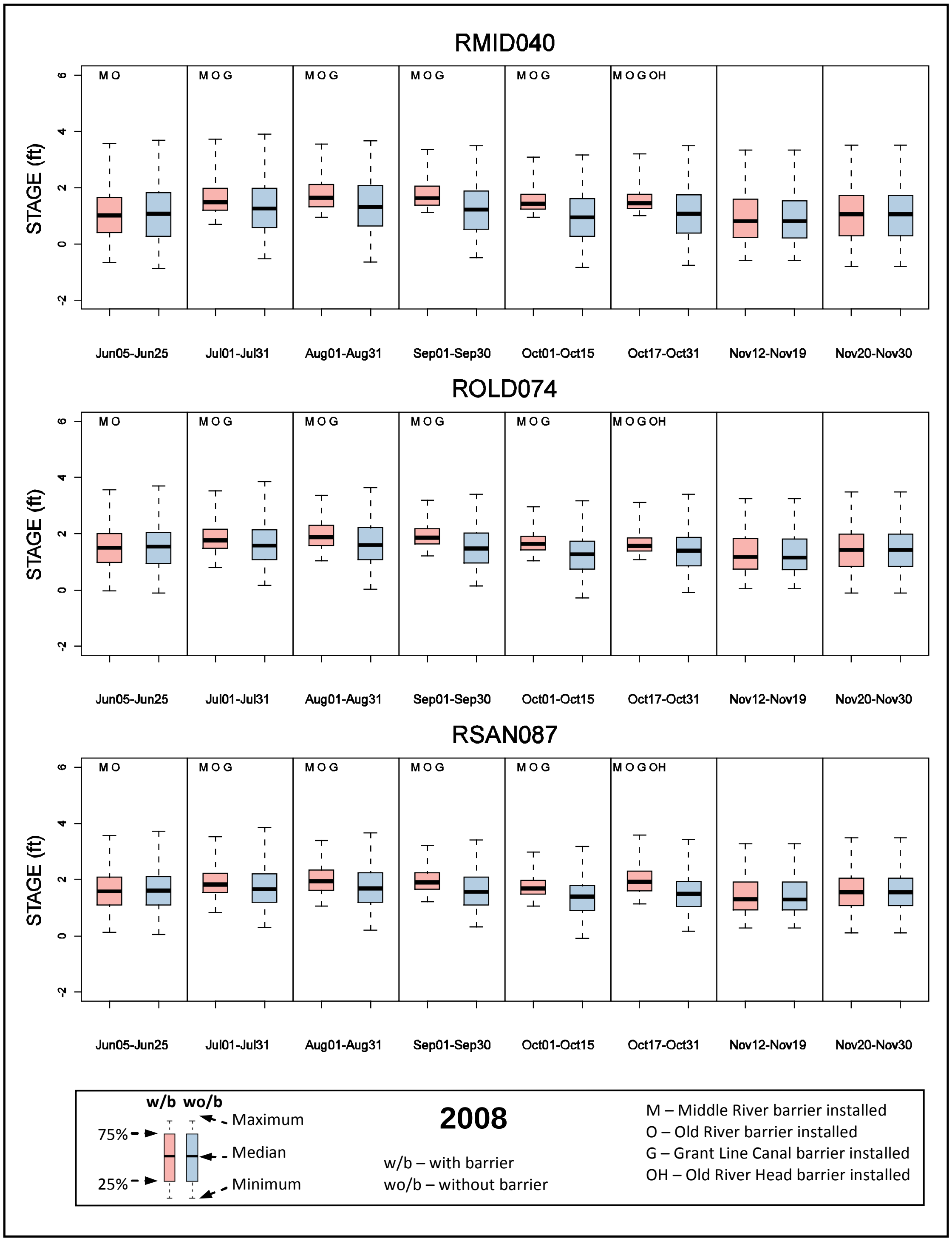

RMID040
STAGE (ft)
M O
M O G
M O G OH
Jun05-Jun25
Jul01-Jul31
Aug01-Aug31
Sep01-Sep30
Oct01-Oct15
Oct17-Oct31
Nov12-Nov19
Nov20-Nov30
ROLD074
RSAN087
w/b
wo/b
Maximum
75%
Median
25%
Minimum
2008
w/b – with barrier
wo/b – without barrier
M – Middle River barrier installed
O – Old River barrier installed
G – Grant Line Canal barrier installed
OH – Old River Head barrier installed

Figure 7-10. Distribution of DSM2-simulated flows for historical 2008 conditions with and without temporary barriers installed

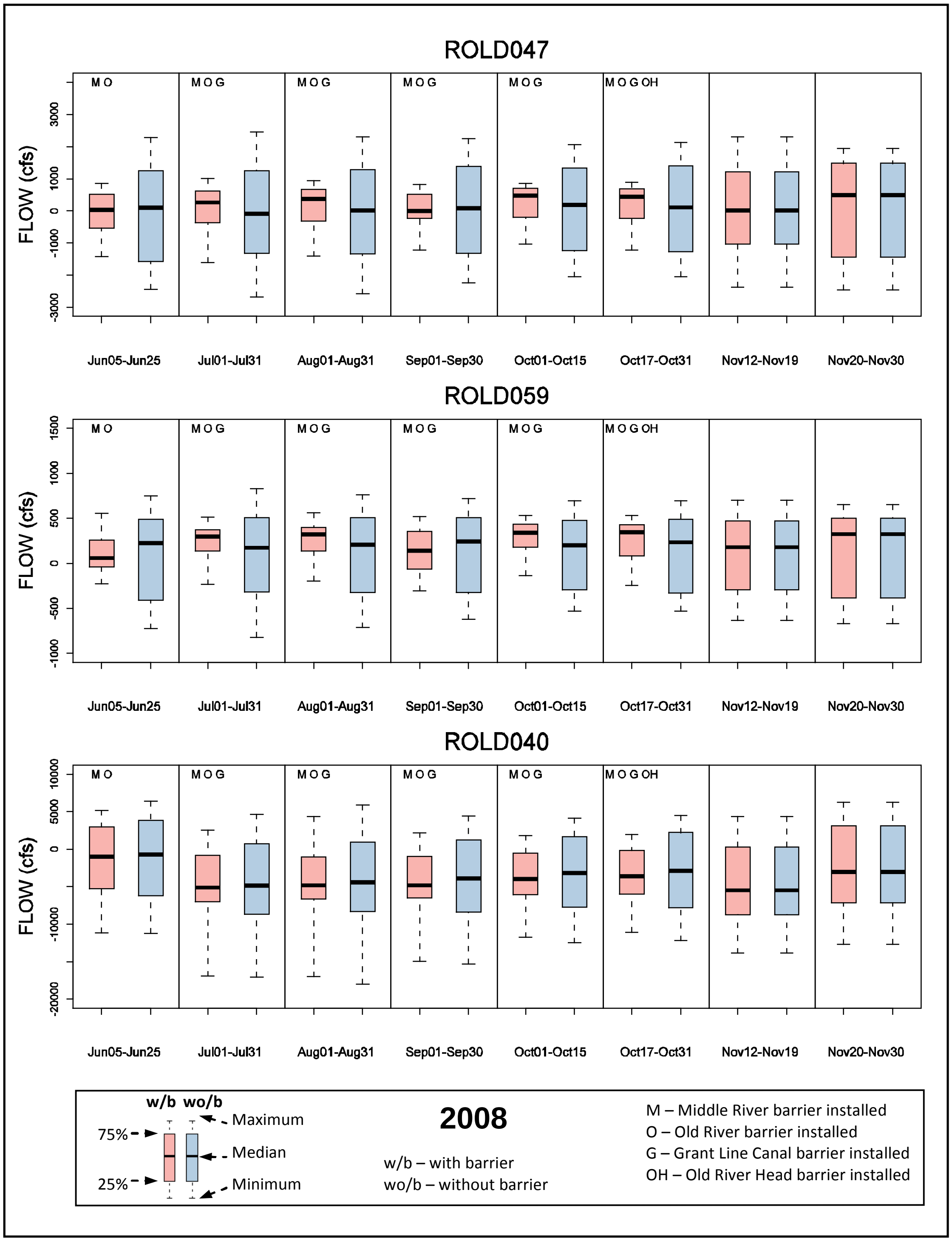


Figure 7-10 (cont.). Distribution of DSM2-simulated flows for historical 2008 conditions with and without temporary barriers installed

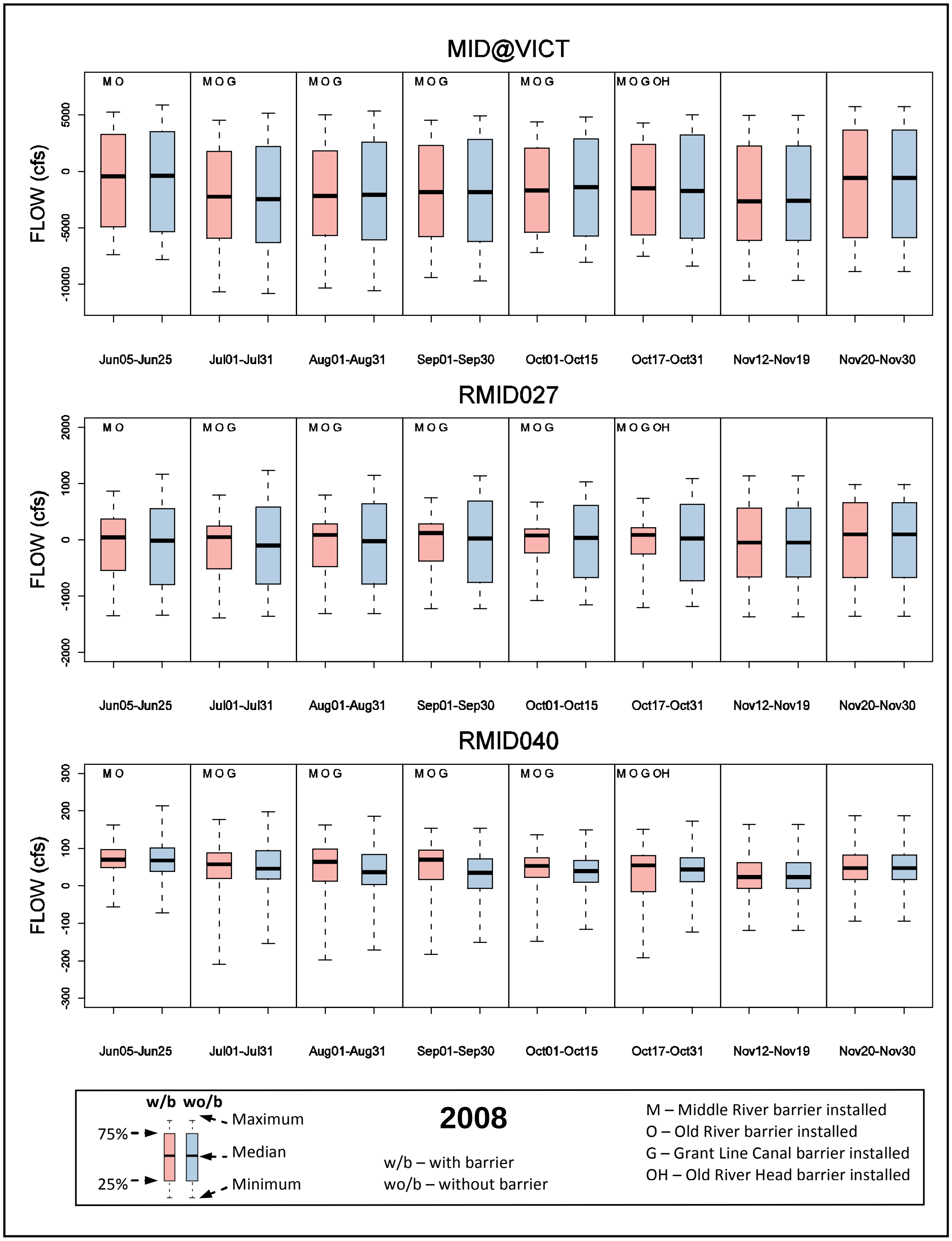

MID@VICT
RMID027
RMID040
FLOW (cfs)
M O
M O G
M O G OH
Jun05-Jun25
Jul01-Jul31
Aug01-Aug31
Sep01-Sep30
Oct01-Oct15
Oct17-Oct31
Nov12-Nov19
Nov20-Nov30
w/b
wo/b
Maximum
75%
Median
25%
Minimum
2008
w/b – with barrier
wo/b – without barrier
M – Middle River barrier installed
O – Old River barrier installed
G – Grant Line Canal barrier installed
OH – Old River Head barrier installed

Figure 7-10 (cont.). Distribution of DSM2-simulated flows for historical 2008 conditions with and without temporary barriers installed

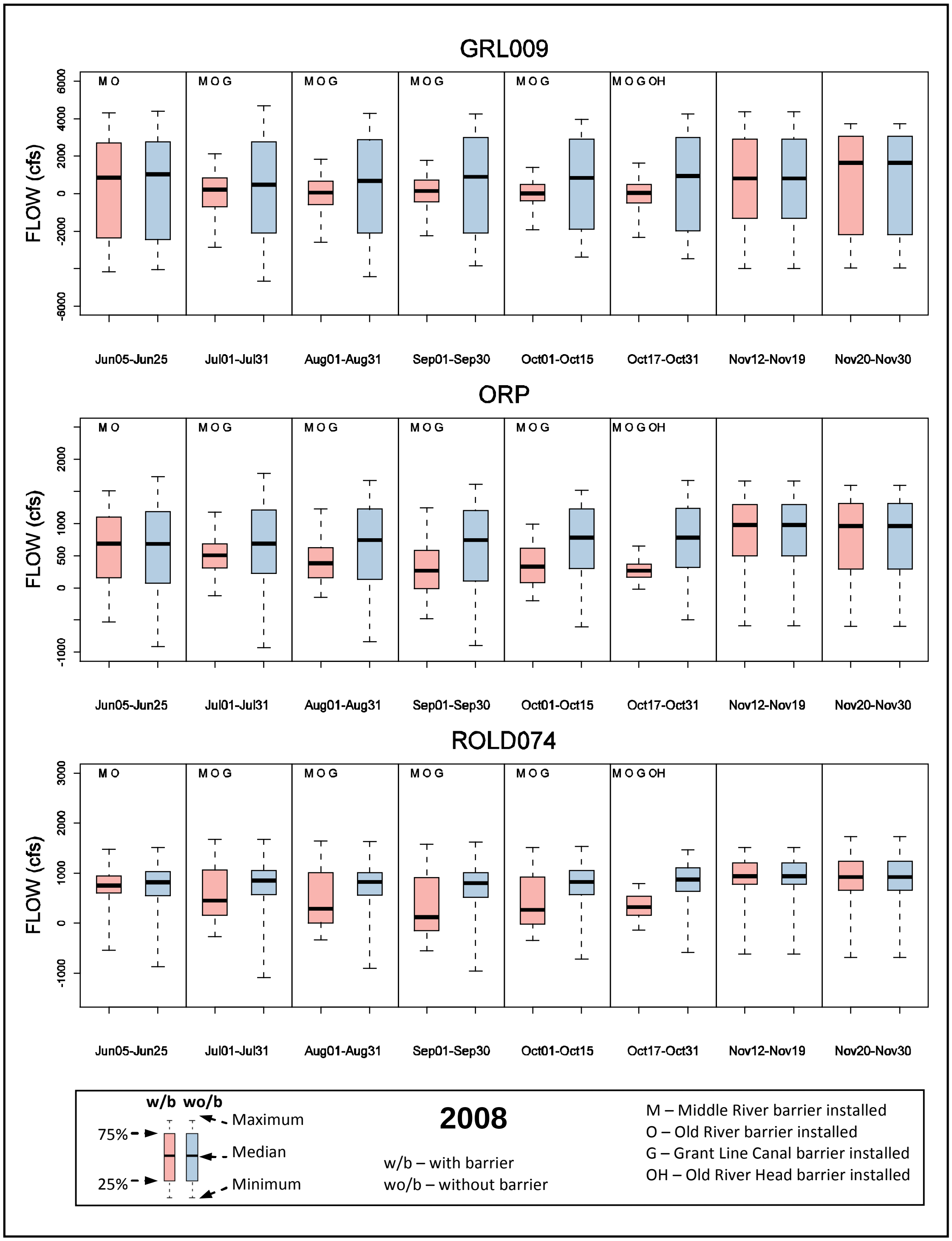


Figure 7-10 (cont.). Distribution of DSM2-simulated flows for historical 2008 conditions with and without temporary barriers installed

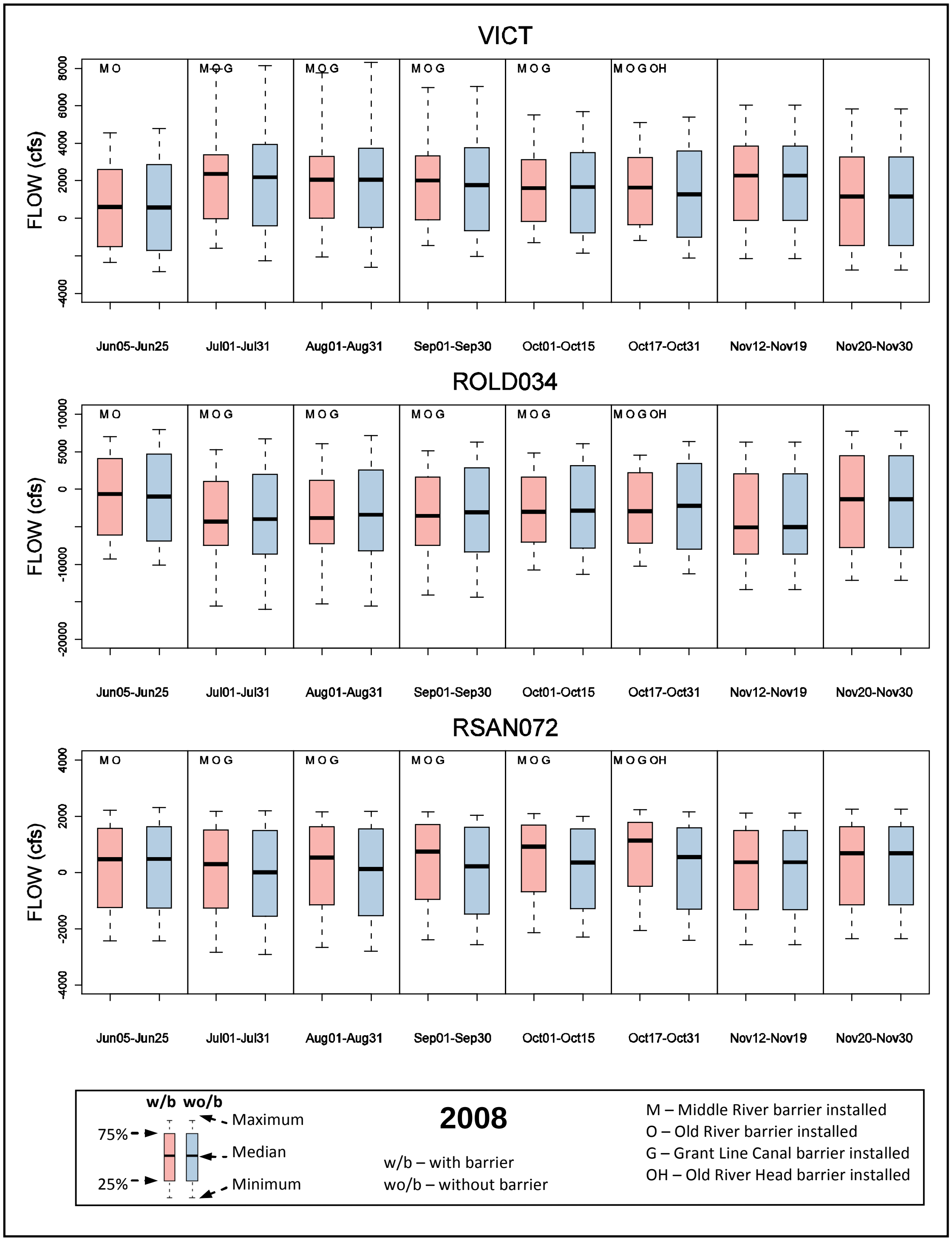
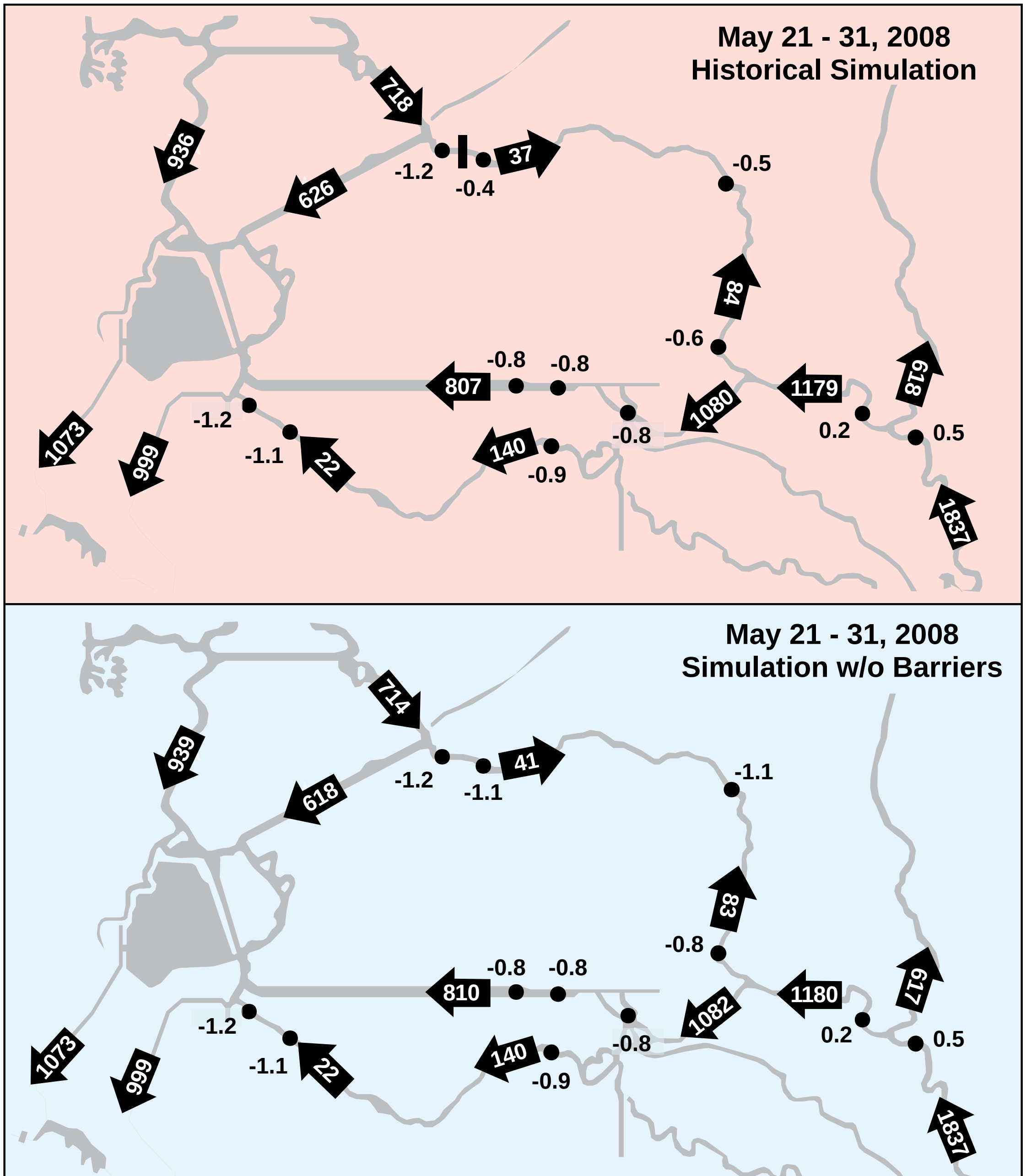


Figure 7-11. Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition



1000 Average flow (cfs) and direction	Period Average Conditions	Sac R + Yolo 11,088 cfs	SWP 1,073 cfs
-0.4 Minimum stage (ft)		SJR 2,023 cfs	CVP 999 cfs

Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition

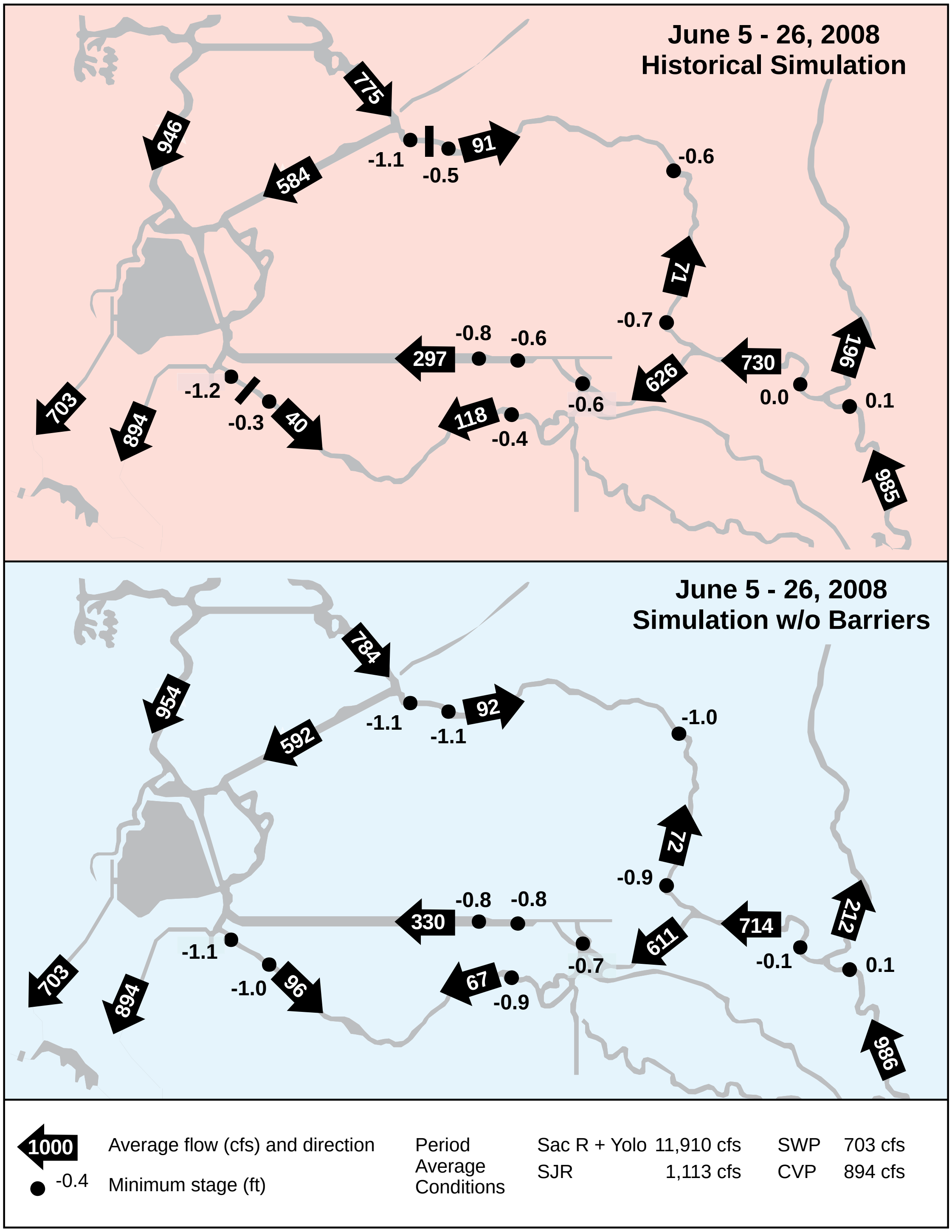


Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition

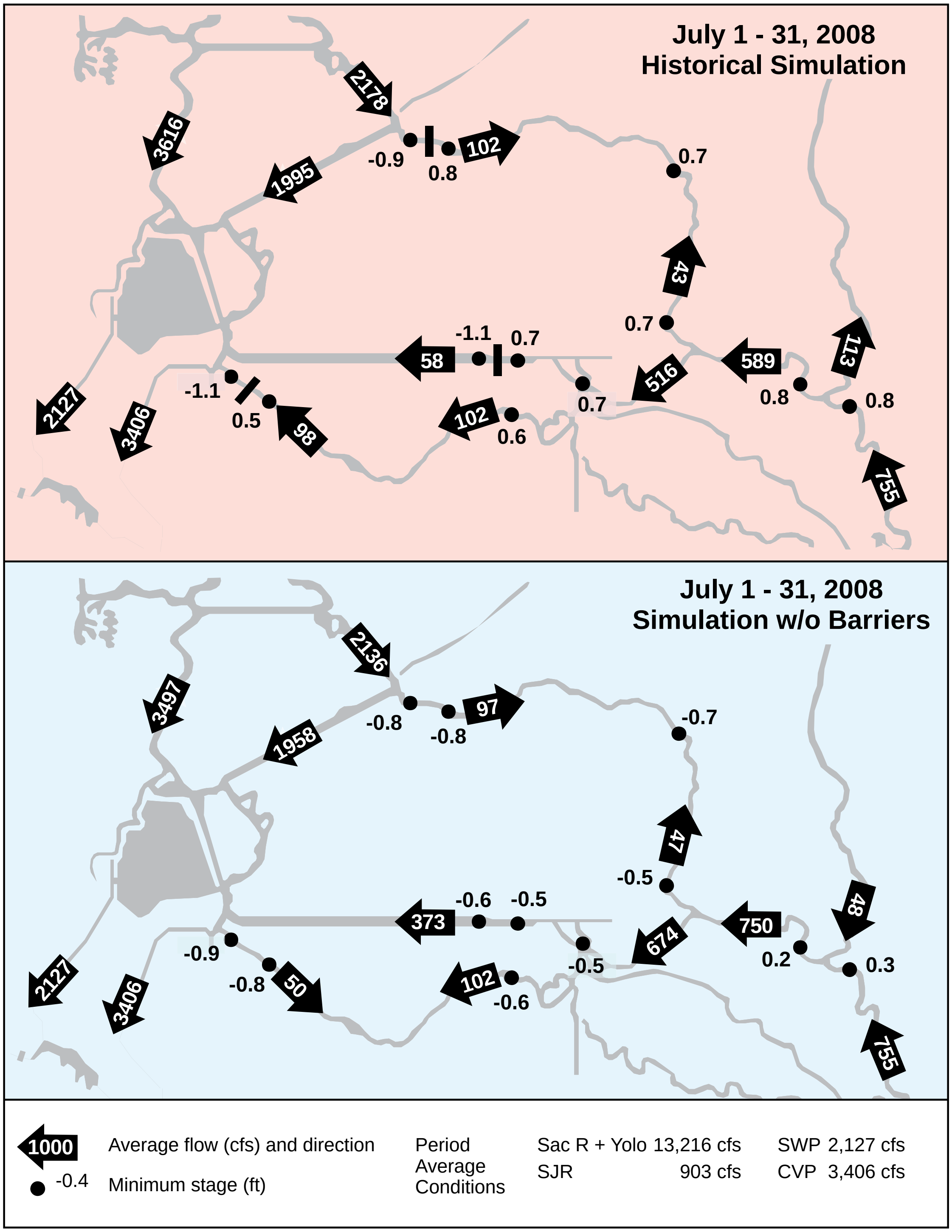


Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition

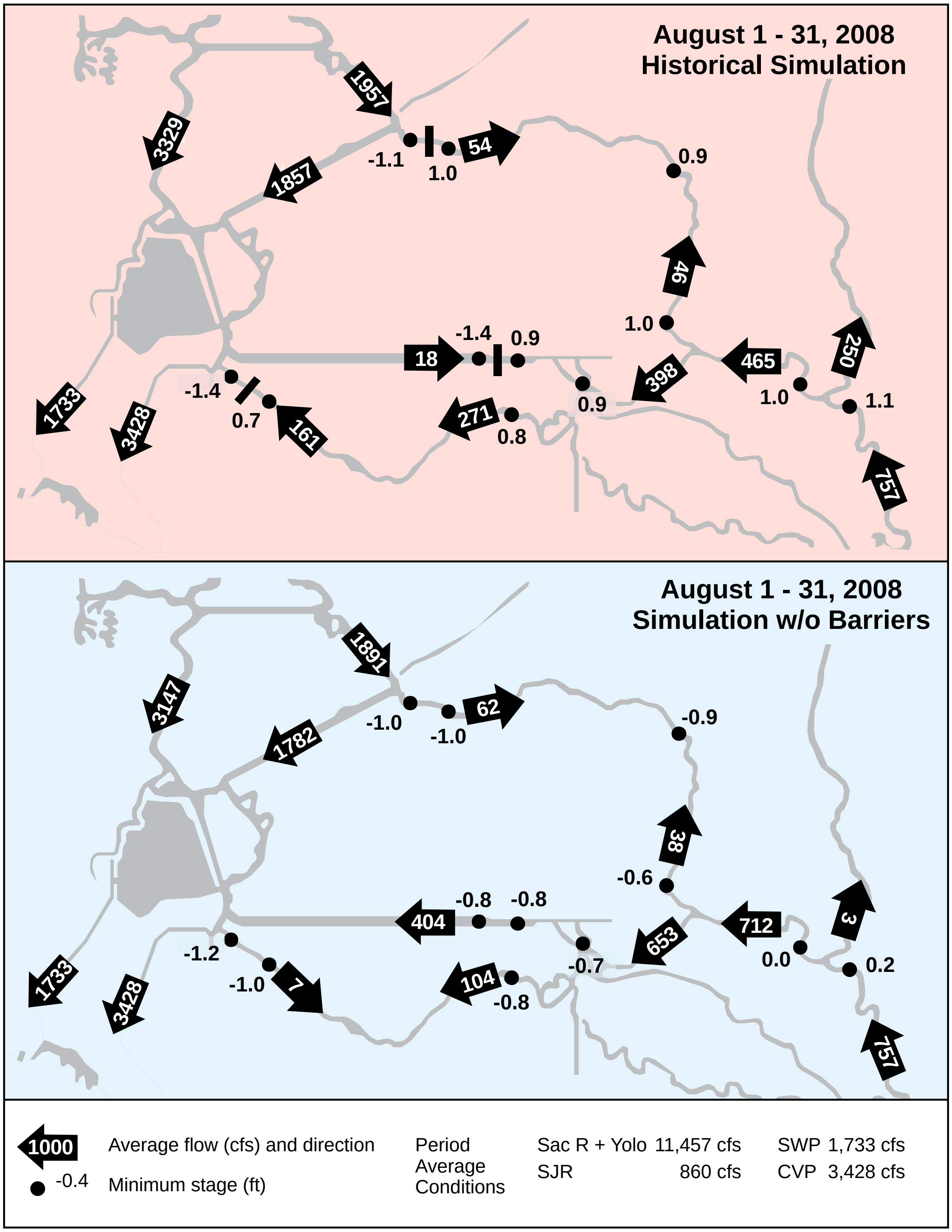


Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition

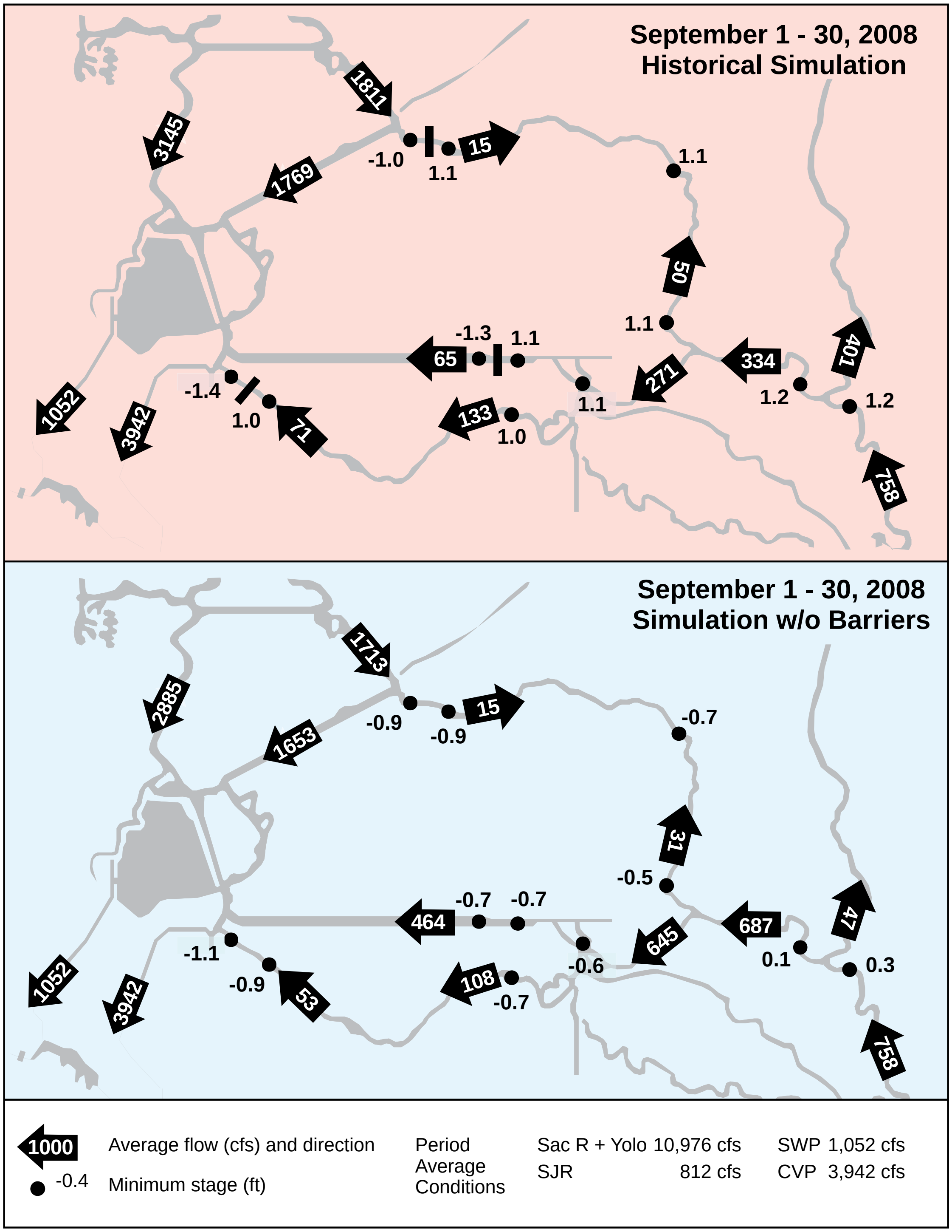


Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition

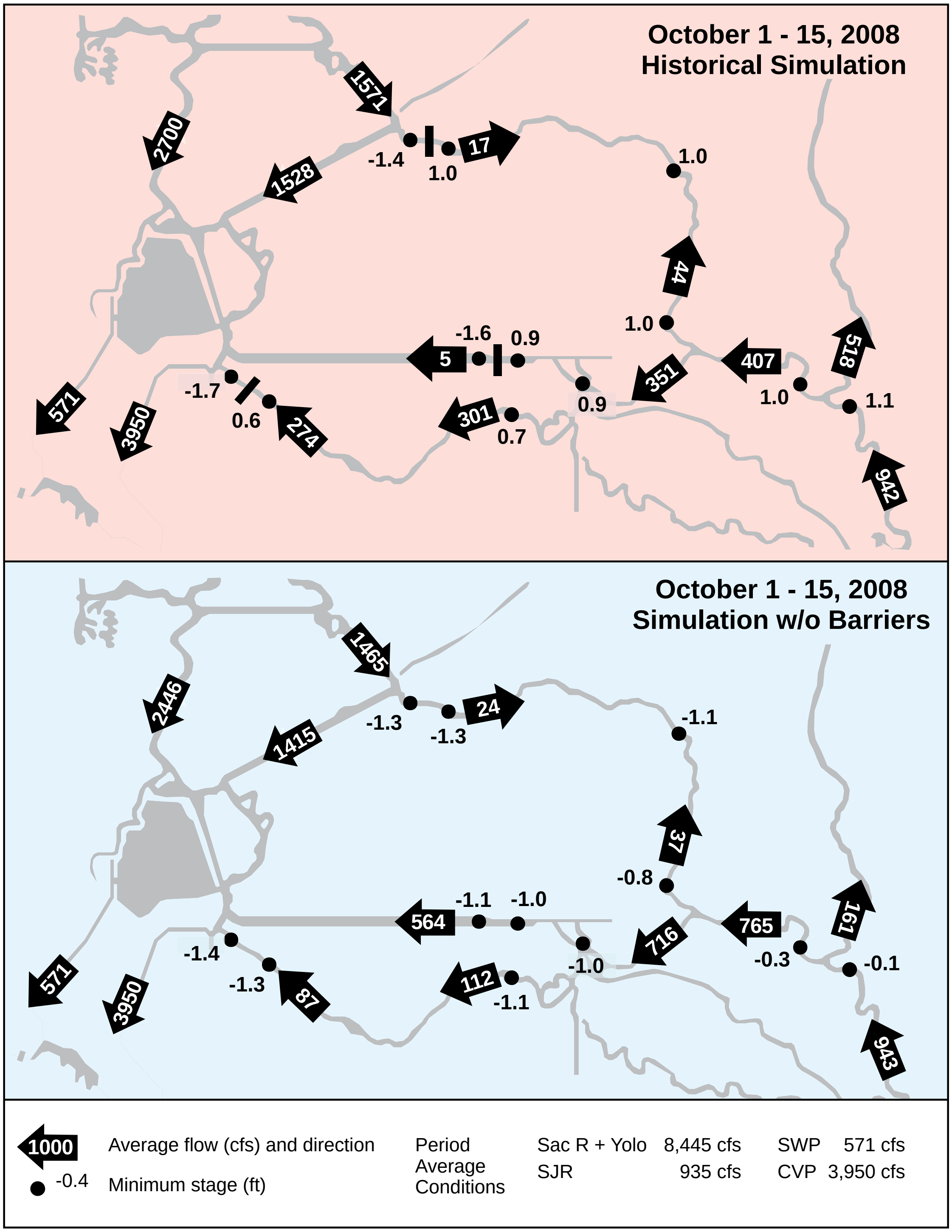
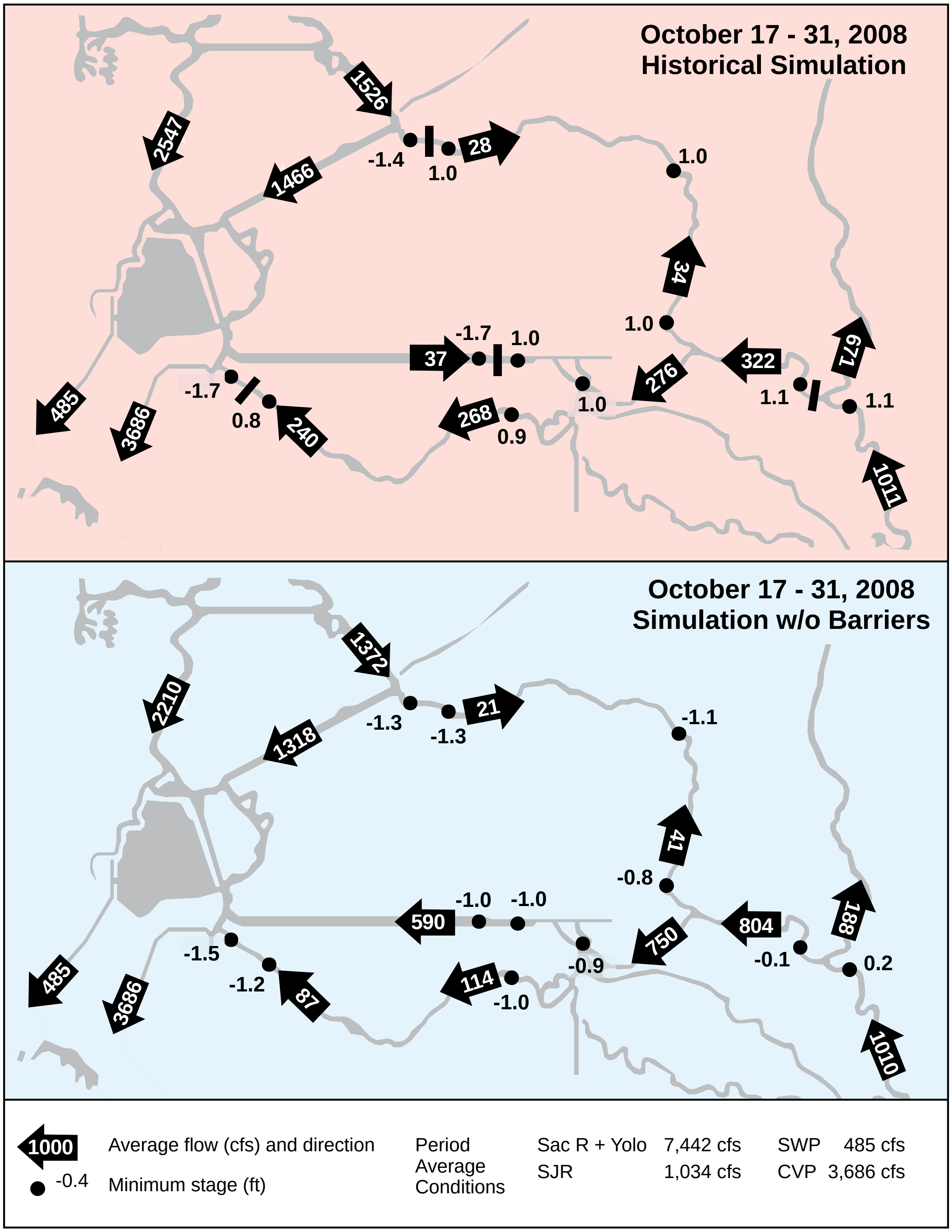


Figure 7-11 (cont.). Simulated period-average flow and minimum stage for 2008 conditions with historical barrier configuration and no-barriers condition



Appendix A. Chinook Salmon Survival Investigations[1]

Contents

[1] This appendix is a republication of Appendix C, Chinook Salmon Survival Investigations, in *2008 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*, prepared by the San Joaquin River Group Authority for the California Water Resources Control Board in compliance with D-1641 in January 2009.

A1: Water Temperature Monitoring Locations

Figure A-1. Water temperature monitoring locations

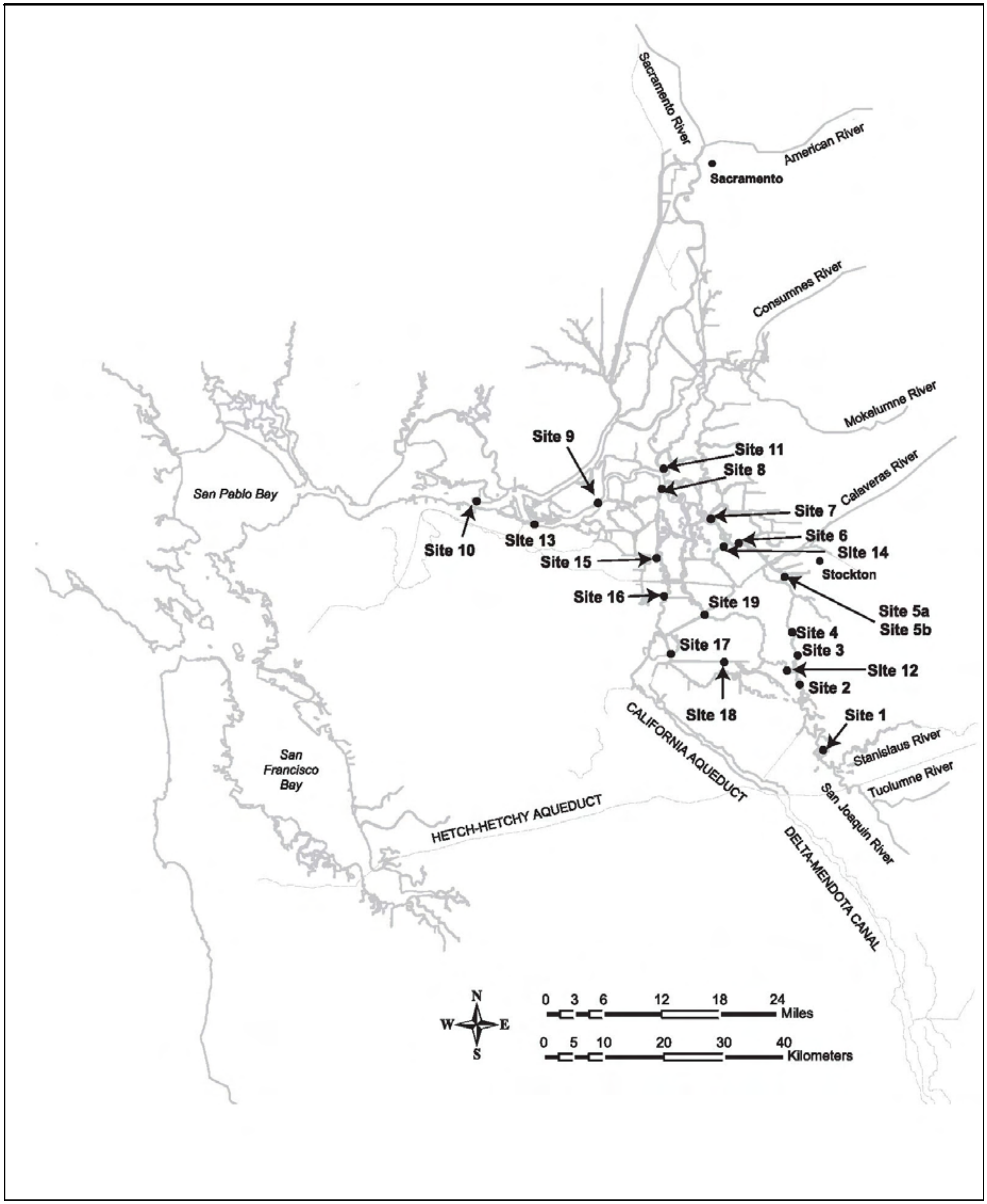
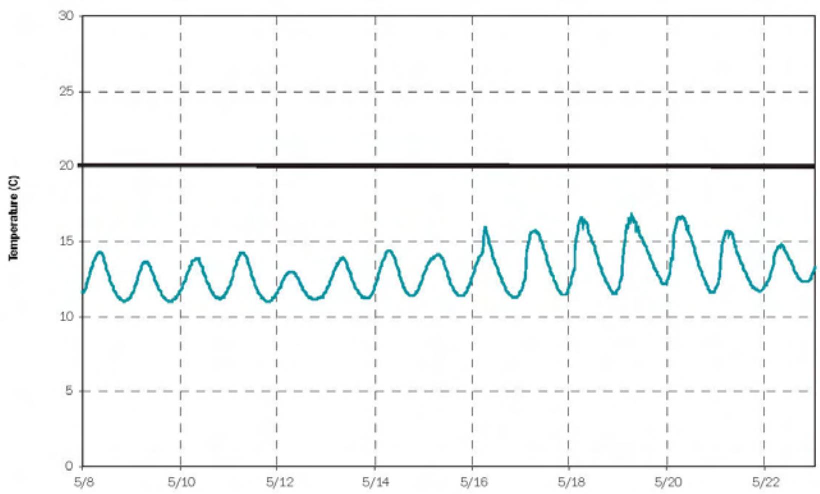


Table A1-1. Water Temperature Monitoring Locations, 2008

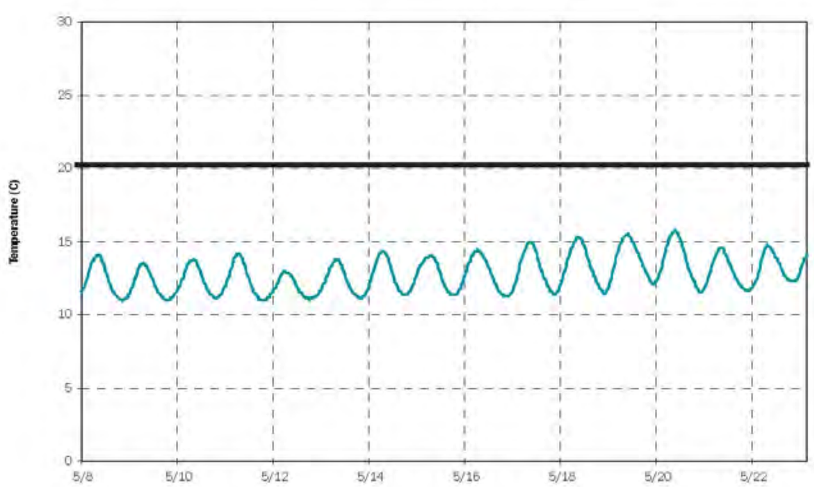
Site	Logger number	Temperature monitoring location	Latitude	Longitude	Distance from Durham Ferry (miles)	Date deployed (2008)	Date retrieved (2008)
A	1284070	Merced River Hatchery Raceway — 1	N/A	N/A	N/A	May 8	May 23
B	1284071	Merced River Hatchery Raceway — 2	N/A	N/A	N/A	May 8	May 23
C	1271942	Merced River Hatchery — source tank	N/A	N/A	N/A	Apr 25	May 8
1	1027492	Durham Ferry	N 37 41.260	W 121 15.604	0	Mar 14	Jun 7
2	1259805	Mossdale	N 37 47.180	W 121 18.425	11	Mar 14	Jun 5
3	1259815	Old River at HORB	N 37 48.634	W 121 19.231	14	Mar 14	Jun 5
4	1027494	Dos Reis	N 37 49.808	W 121 18.665	16	Mar 14	Jun 5
5	1259804	DWR monitoring station	N 37 51.877	W 121 19.386	19	Mar 14	Jun 5
6a	1259807	Confluence — top	N 37 56.818	W 121 20.285	27	Mar 14	Jun 5
6b	1259808	Confluence — bottom	N 37 56.818	W 121 20.285	27	Mar 14	Jun 5
7	1259798	Upstream of Channel Marker 33	N 37 59.684	W 121 24.694	33	Mar 15	Jun 5
8	1259813	Turner Cut (Channel Marker 21-22)	N 37 59.468	W121 27.267	35	Mar 15	Jun 5
9	259806	Half-mile upstream of Channel Marker 13 (“Q” Piling)	N 38 01.948	W 121 28.768	37	Mar 15	Jun 5
10	1259812	All Pro abandoned boat	N 38 04.520	W 121 34.422	45	Mar 15	Jun 6
11	1259796	USGS Gaging Station at Jersey Point	N 38 03.172	W121 41.637	56	Mar 14	Jun 6
12	1259810	Antioch Marina	N 38 01.369	W121 48.686	64	Mar 17	Jun 6
13	1259795	Chipps Island	N 38 03.010	W 121 55.034	72	March 17	Jun 6
14	1259797	Holland Riverside Marina	N 37 58.323	W 121 34.887	South Delta	Mar 15	Jun 6
15	1259811	Old River/Indian Slough confluence	N 37 54.954	W 121 33.949	South Delta	Mar 15	Jun 7
16	1259814	CCF Radial Gates	N 37 49.773	W 121 33.096	South Delta	Mar 15	Logger malfunction
17	1259803	Grant Line Canal at Tracy Boulevard Bridge	N 37 49.143	W 121 27.026	South Delta	Mar 15	Jun 6
18	1259800	Middle River at Victoria Canal confluence	N37 53.323	W121 29.334	South Delta	Mar 15	Jun 6
19	1259801	Werner Cut (channel above Woodward Isle)	N 37 56.319	W 121 30.584	South Delta	Mar 15	Jun 6

A2: Water Temperature Monitoring Data, Plots 1-19

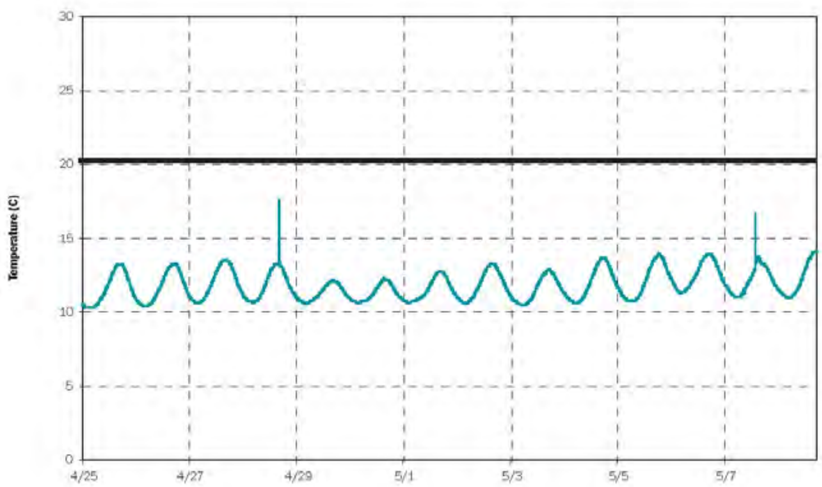
Site A. Merced River Hatchery Raceway — 1



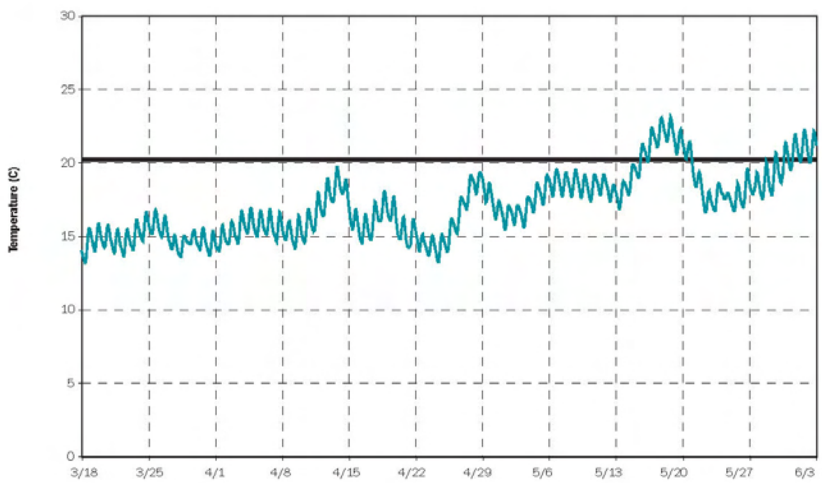
Site B. Merced River Hatchery Raceway — 2



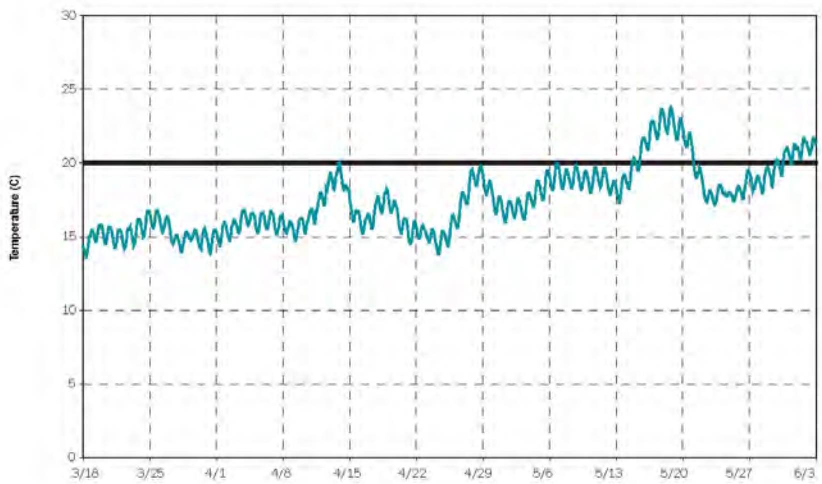
Site C. Merced River Hatchery — source tank



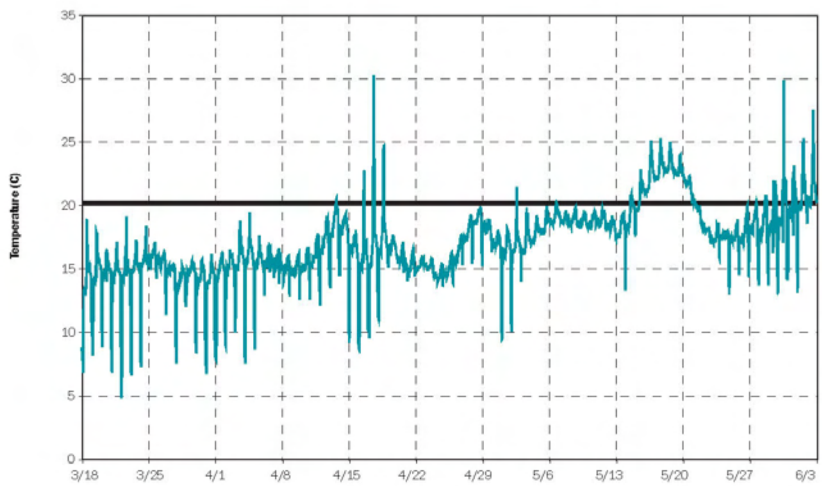
Site 1. Durham Ferry



Site 2. Mossdale

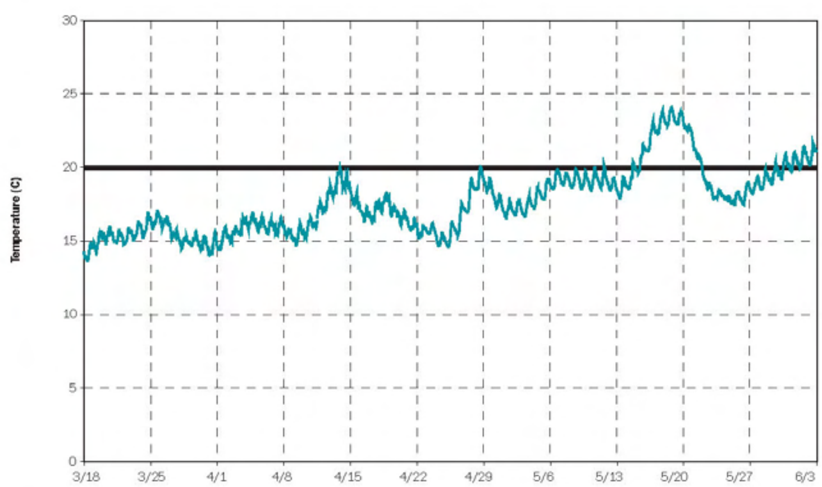


Site 3. Old River at HORB

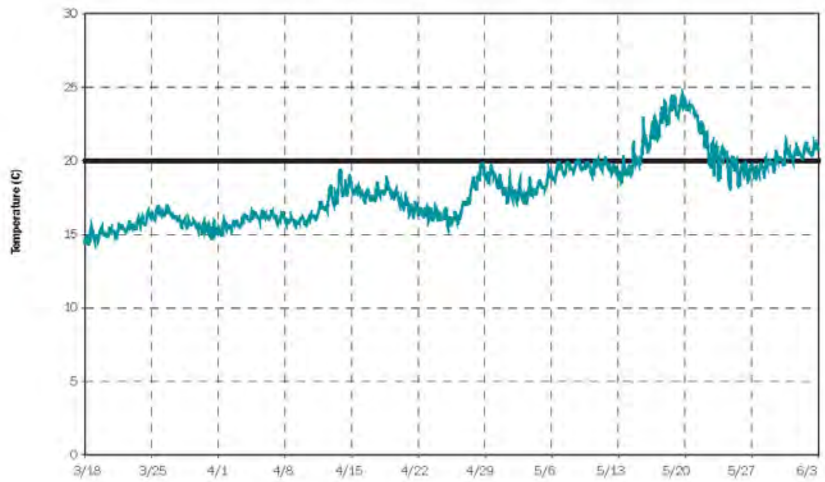


Site 4. Dos Reis

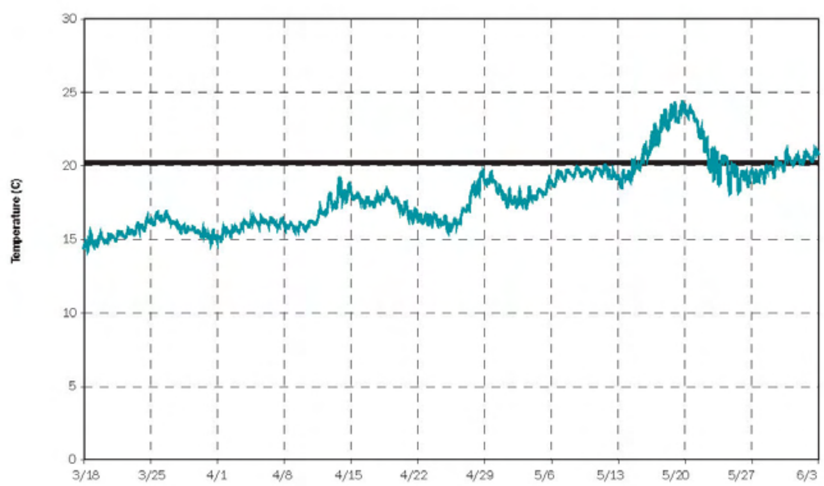
Site 5. DWR monitoring station



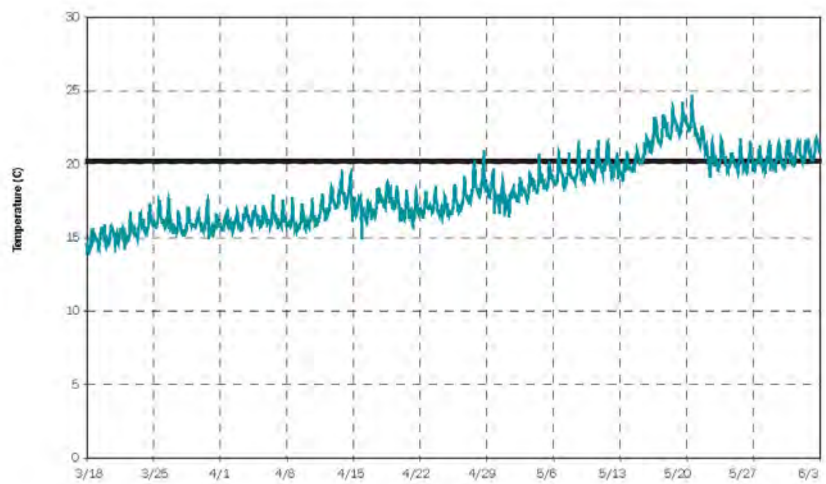
Site 6a. Confluence — top



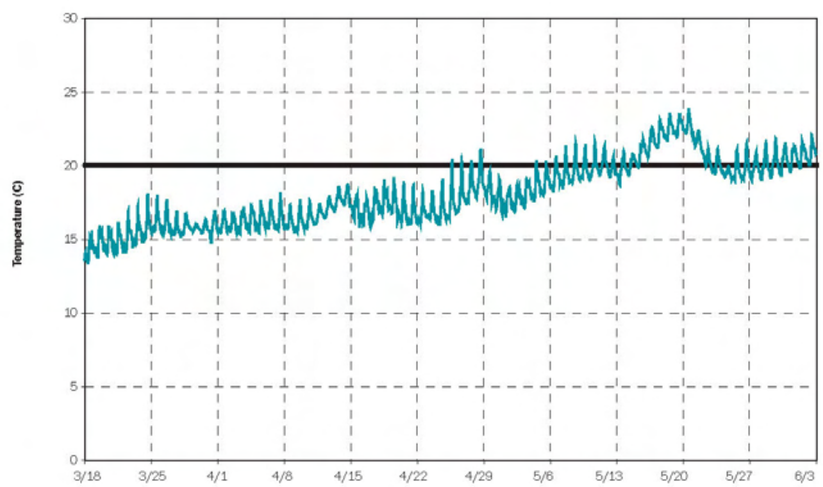
Site 6b. Confluence — bottom



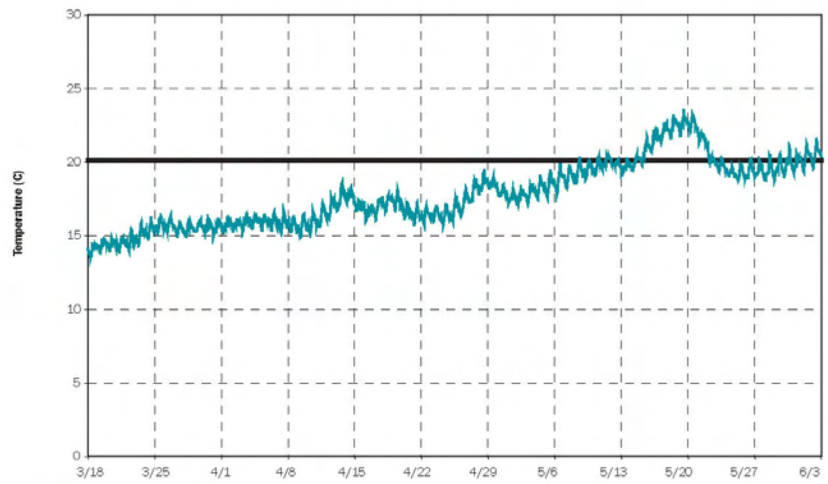
Site 7. Upstream of Channel Marker 33



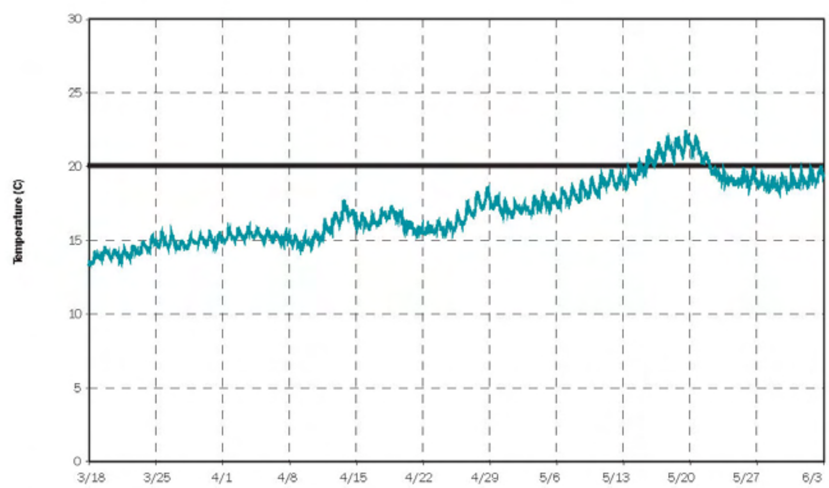
Site 8. Turner Cut



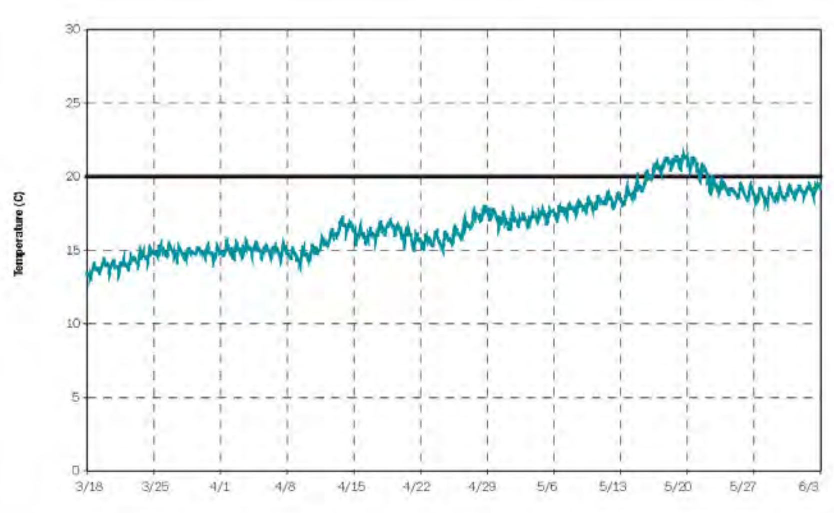
Site 9. Half-mile upstream of Channel Marker 13



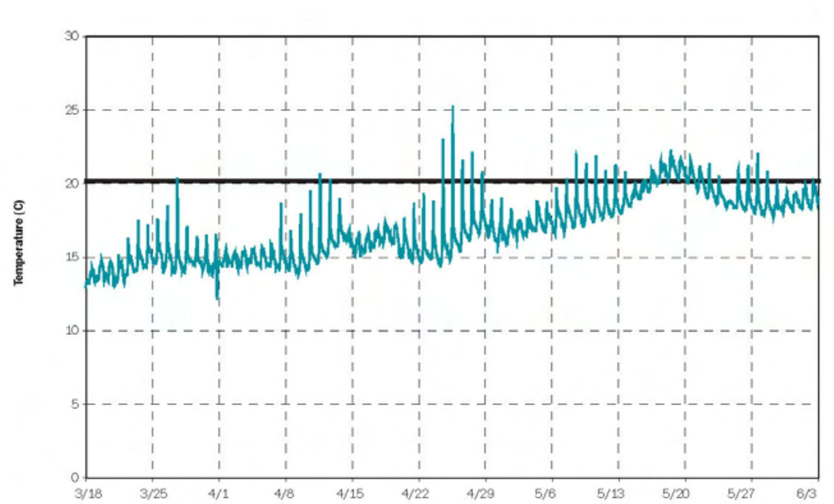
Site 10. All Pro abandoned boat



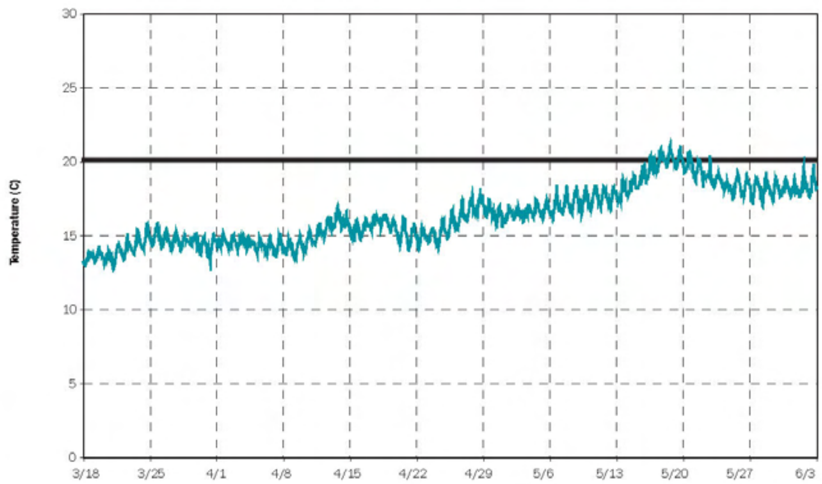
Site 11. USGS Gaging Station at Jersey Point



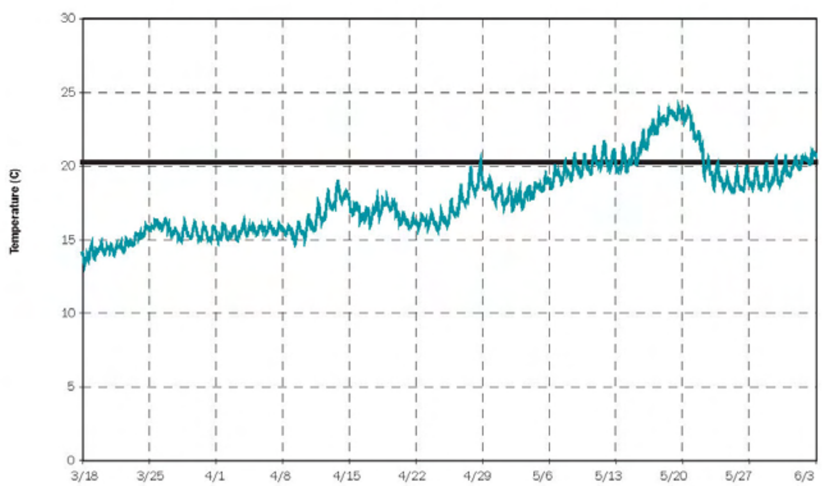
Site 12. Antioch Marina



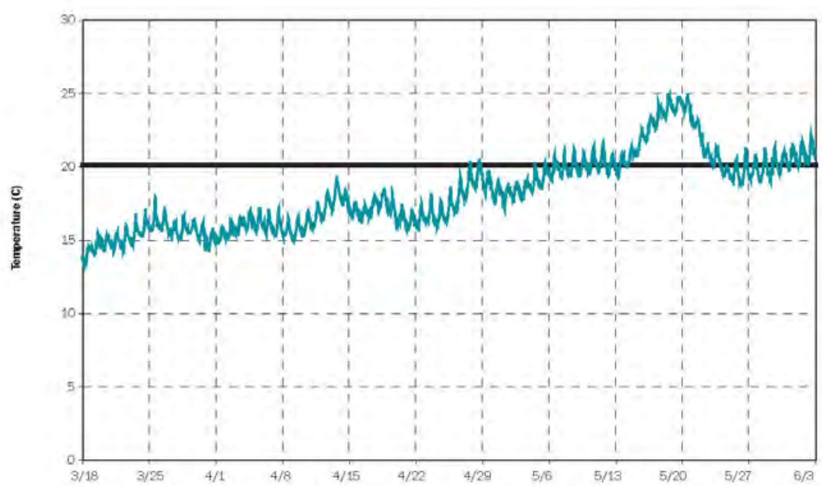
Site 13. Chipps Island



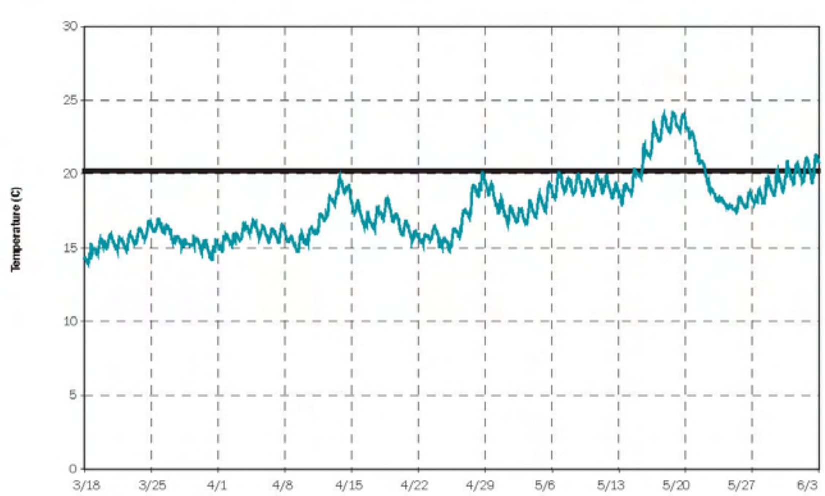
Site 14. Holland Riverside Marina



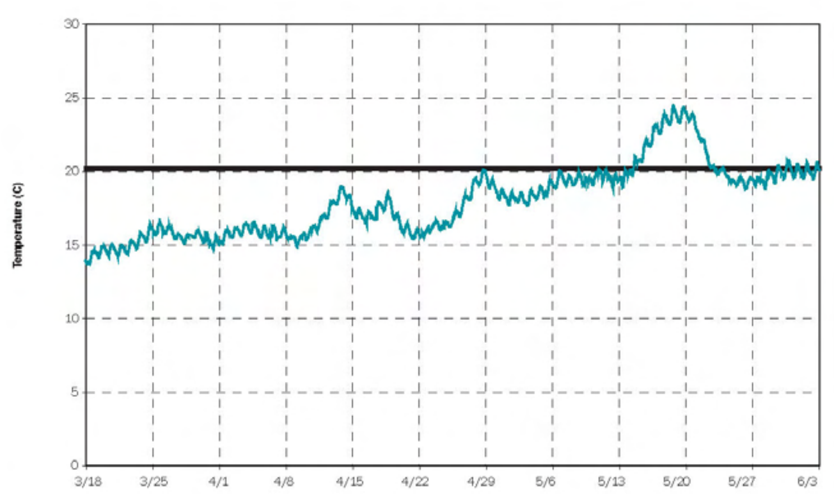
Site 15. Old River/Indian Slough confluence



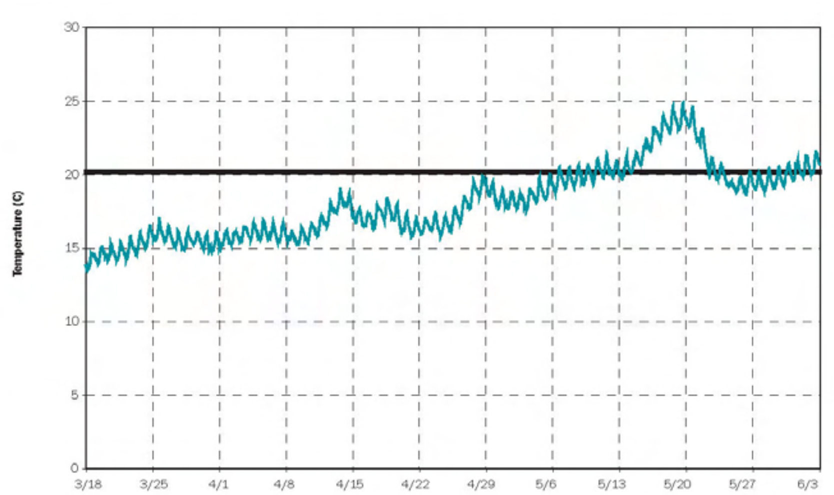
Site 17. Grant Line Canal at Tracy Boulevard Bridge



Site 18. Middle River at Victoria Canal confluence



Site 19. Werner Cut



A3. Preliminary Summary of Tag Life Evaluation

Preliminary summary of tag life evaluation, tag failure rates, and sample size reductions during the 2008 VAMP smolt emigration study. Provided by: US Geological Survey, Columbia River Research Laboratory.

Background

Acoustic telemetry was used to estimate survival, distribution, and travel times of migrating juvenile Chinook salmon through the lower San Joaquin River and Sacramento-San Joaquin Delta as part of the 2008 VAMP study. Because premature tag failure can result in biased survival estimates from fixed-station telemetry studies, an in-tank tag life extinction study was conducted to quantify the rate of tag extinction under the operating parameters used. HTI model 795-S acoustic transmitters (hereafter referred to simply as S tags) were selected for the 2008 VAMP studies largely because of their small size. The S tag, weighing 0.65 g in air, was recently introduced by HTI as a replacement for the 0.70-g 795-M tag. The S tag was expected to perform equally to the M tag in terms of source level (i.e., detection range) and reliability (i.e., tag life). Based on results from 6 separate in-tank tag extinction studies using M-tags in the Columbia River Basin between 2004 and 2007, it was anticipated that minimum tag life for the S tags under this study's operating parameters (double-pulse encoding, 8–10 second period range, 2 millisecond (ms) pulse width, CODE 2 pulse width encoding) would be no less than 11 days.

Methods

Tag life studies were conducted at the USGS Columbia River Research Laboratory (CRRL) in Cook, Washington. A stratified random sample of 50 S tags was collected from all 1001 S tags initially allocated to the study. On May 21, 2008, study participants attempted to program (i.e., initialize) all 50 tags. Tag programming methodologies were consistent with those used in the field study (i.e., tags that were implanted into study fish and released into the river). Upon initial programming, each tag was "sniffed" in a cup of water using an HTI sniffer and monitored through at least 3 transmission cycles (e.g., one cycle = "doublepulse" followed by 8–10 seconds' delay and subsequent doublepulse). Any tag that failed to program was returned to HTI. At least 5 attempts were made to program each tag. Tags that operated properly were affixed to a vertical PVC stand with hook and loop closure in a fiberglass tank (1.7-meter diameter) within 2 minutes of activation. The tank received a continuous supply of fresh water throughout the duration of the study. Inflow temperature was thermostatically controlled to match the water temperature of the San Joaquin River at Jersey Point on each day of the field study. Water temperature was also logged every 30 minutes on a temperature logger at the bottom of the tank (Onset Tidbit). An acoustic receiver (HTI model 291) with two hydrophones continuously monitored tags in the tag life tank. Detection files were processed daily to determine proper function of each tag. Tags were considered "dead" when they were not detected during any single 1-hour interval. The date and time of final transmission was recorded for each tag. The active duration was calculated as the elapsed time between initial programming and final transmission.

During the field study, HTI provided an additional 94 S tags (i.e., "replacement tags") to replace tags that failed to program. To identify differences in tag life between the two batches (i.e., "original" vs. "replacement"), study participants conducted a second tag life study in the same tank with an additional 27 S tags. Unlike the original tags, however, the 27 replacement tags were not a subsample of the 94 used in the study, but were provided separately by HTI at a later date. Tag life study for replacement tags commenced on May 30, 2008. Programming and monitoring methodologies were consistent with those used for the original tags.

In the field study, tagged fish were released about 24 hours after tag programming and implantation. During this 24-hour period, all tags were held in a holding tank and monitored by an acoustic telemetry receiver. Non-active tags or tags that ceased operation were identified and removed from future analyses.

Thus, any tag that failed during the first 24 hours was effectively removed from the sample, and sample sizes at each release were reduced accordingly. Similarly, although tag failure in the tag life study during the first day was documented and reported, these tags were not considered part of the sample that was used to infer tag life in the field.

Results/Discussion

A fundamental assumption of mark-recapture survival models is that no tags cease operation during the study period or within the study region. Premature tag failure results in biased survival estimates because such failure cannot be separated from fish mortality. The proportions of original tags that failed to initialize or ceased operation within 24 hours of initial programming were 23% and 24% for tags used in the field and tag life studies, respectively; and 14% and 4% for replacement tags (Table A3-1). The proportions of failures were consistent between tag life and field studies for original tags, but not replacement tags. It was suspected that this was because the replacement tags used in the tag life study originated from a different manufacturing lot than the replacement tags used in the field study. Additionally, replacement tags used in the tag life study may have undergone more extensive quality assurance/quality control by HTI prior to delivery.

Continuous monitoring of tag operation prior to transport and release allowed for documentation of premature failure within this short interval (i.e., “infantile failure”). Effective removal of such tags from each release group (i.e., treating them as if they were never released) eliminates bias. Although such censoring of individuals reduces precision about fish survival estimates, this study favored less precise, unbiased estimates over more precise, biased estimates. The reduction in sample sizes due to infantile failure ranged from 9% to 19% among release groups (Table A3-2).

The in-tank tag life study was necessary to infer the probability of premature tag failure for fish released into the river. In the tag life study, original tags began to fail within 3 days of initial programming (Figure A3-1), and tag failure exceeded 10% after 8 days for both batches. Although it was expected that all tags would last more than 11 days, 21% and 12% of original and replacement tags, respectively, ceased operation within 11 days of initial programming. All tags expired within 20 days.

Because the rate of tag failure during any day was conditional on the number of tags available at the start of each day, the rate of successes (or alternatively failures) through time is best graphically examined on a logarithmic scale. On such plots, a linear association among points indicates constant rate of loss. Logarithmic tag life curves for both original and replacement tags seem to be characterized by two distinct periods with respect to failure rates (Figure A3-1). During the expected “operational phase,” (i.e., between days 1 and 11), the average daily rate of failure was 2.3% and 1.3% failure/day for original and replacement tags, respectively. This higher-than-expected rate of failure during the operational phase will bias estimates of fish survival from the 2008 VAMP study, because tag failure cannot be separated from fish mortality. The high rate of failure after 17 days for both batches is likely indicative of normal battery expiration. It seems that if failure were limited to this phase alone, minimum battery life would have approached or exceeded expectations (i.e., no less than 11 days). It will be necessary to identify causes of failure during the operational phase in order to eliminate bias in survival estimates from mark-recapture studies using these tags in future studies.

Table A3-1. Number and proportion of HTI model 795-S tags that failed to initialize or ceased operation within 24 hours of programming during the 2008 VAMP smolt emigration study (preliminary data)

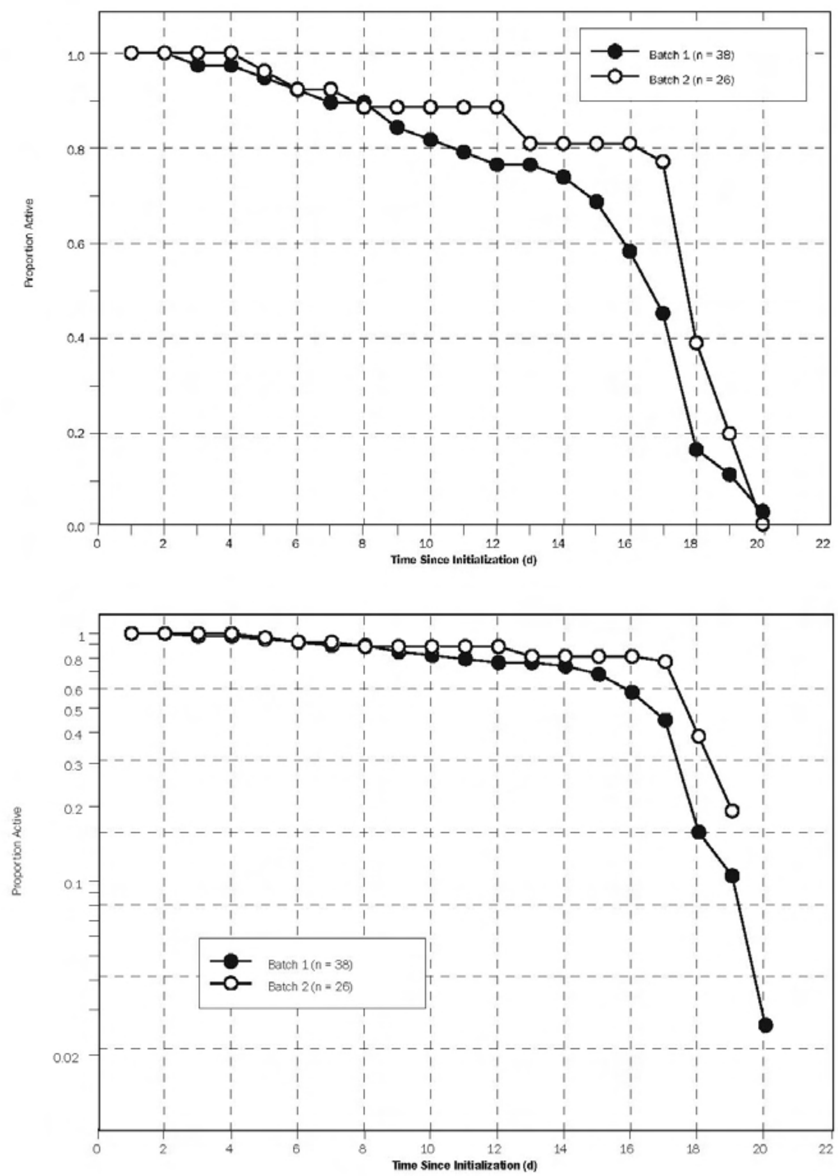
			Premature failures, Number (% of N)		
Batch	**Usage**	**N**	**0 < 2 hours**	**2 < 24 hours**	**Total**
Original	Field study	951	194 (0.20)	24 (0.03)	218 (0.23)
	Tag life	50	11 (0.22)	1 (0.02)	12 (0.24)
Replace ment	field study	94	13 (0.14)	0 (0.00)	13 (0.14)
	Tag life	27	0 (0.00)	1 (0.04)	1 (0.04)

Table A3-2. Reduction in sample sizes due to premature failure of HTI model 795-S tags during the 2008 VAMP smolt emigration study (preliminary data)

Release	Intended sample size	True sample size	% change
DF1	285	241	-0.15
ST1	190	161	-0.15
DF2	285	258	-0.09
ST2	190	154	-0.19

Figure A3-1. Proportion of acoustic tags that remained active on each day of the 2008 VAMP tag life study, of those tags active one day after initialization

**(Presented on the (A) linear and (B) semi-log scales.
Batch 1 = original tags; Batch 2 = replacement tags.) (Preliminary data.)**



Appendix B. Stage and Flow Data

This appendix consists of the stage and flow data that are presented graphically in this report. The values are derived from 15-minute simulated stage and flow over each of the 20 time periods in 2008 presented in Table 7-3.

Figure B-1. Locations' stage and flow data presented for the simulation of 2008 hydrodynamics

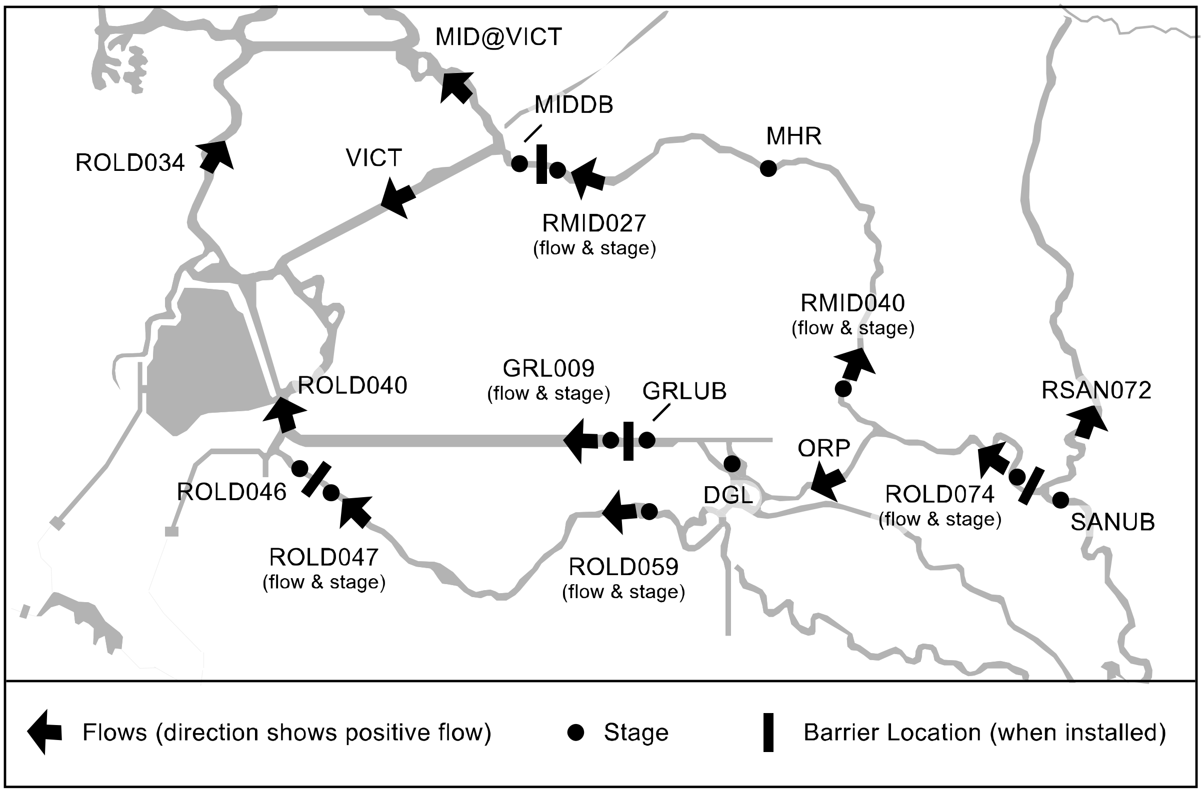


Table B-1. Distribution of stages (feet) by study period in 2008: historical barrier configurations

		GRL009					GRLUB					DGL				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-0.78	-0.05	0.54	1.24	2.61	-0.74	-0.04	0.55	1.23	2.63	-0.75	-0.01	0.60	1.24	2.67
	6 - 21	-0.50	0.54	1.28	1.97	3.88	-0.47	0.55	1.28	1.98	3.88	-0.43	0.59	1.29	2.01	3.90
	22 - 31	-0.33	0.47	1.09	1.82	3.52	-0.29	0.52	1.09	1.85	3.52	-0.29	0.57	1.17	1.91	3.53
Feb	1 - 4	-0.53	0.57	1.12	2.08	3.34	-0.47	0.60	1.15	2.12	3.38	-0.40	0.67	1.23	2.16	3.46
	5 - 13	-0.56	0.06	0.63	1.34	3.40	-0.50	0.10	0.66	1.34	3.39	-0.46	0.12	0.72	1.37	3.38
	14 - 29	-0.73	0.44	1.02	1.95	3.56	-0.70	0.48	1.04	1.97	3.57	-0.69	0.50	1.06	2.00	3.62
Mar	1 - 31	-0.96	0.05	0.82	1.45	3.29	-0.93	0.07	0.84	1.46	3.31	-0.90	0.12	0.85	1.49	3.36
Apr	1 - 30	-0.95	0.14	0.84	1.56	3.03	-0.90	0.17	0.88	1.57	3.03	-0.85	0.19	0.92	1.60	3.05
May	1 - 20	-0.75	0.50	1.24	1.90	3.70	-0.72	0.50	1.25	1.93	3.70	-0.69	0.54	1.26	1.95	3.77
	22 - 31	-0.80	0.32	1.12	1.86	3.77	-0.79	0.34	1.14	1.86	3.77	-0.80	0.35	1.18	1.89	3.78
Jun	5 - 25	-0.80	0.46	1.19	1.92	3.77	-0.62	0.57	1.23	1.88	3.59	-0.59	0.60	1.22	1.88	3.56
Jul	1 - 31	-1.08	0.38	1.25	2.11	4.15	0.71	1.35	1.62	2.02	3.51	0.70	1.35	1.62	2.02	3.54
Aug	1 - 31	-1.42	0.31	1.24	2.15	3.93	0.94	1.48	1.77	2.20	3.35	0.94	1.48	1.77	2.21	3.39
Sep	1 - 30	-1.33	0.09	1.00	2.02	3.74	1.13	1.55	1.79	2.11	3.16	1.13	1.55	1.78	2.11	3.22
Oct	1 - 15	-1.63	-0.21	0.76	1.78	3.38	0.93	1.33	1.58	1.79	2.91	0.93	1.32	1.58	1.79	2.96
	17 - 31	-1.70	-0.12	0.88	1.86	3.56	1.03	1.36	1.55	1.83	2.98	1.03	1.36	1.55	1.83	3.00
Nov	12 - 19	-0.85	0.05	0.64	1.39	3.30	-0.80	0.06	0.66	1.39	3.31	-0.79	0.09	0.68	1.45	3.33
	20 - 30	-1.03	0.14	0.97	1.78	3.55	-1.00	0.17	0.99	1.78	3.54	-0.98	0.19	1.02	1.77	3.54
Dec	1 - 31	-0.89	0.31	1.04	1.86	4.36	-0.85	0.32	1.05	1.87	4.37	-0.83	0.36	1.07	1.87	4.40

		ROLD046					ROLD047					ROLD059				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-1.12	-0.33	0.36	1.10	2.54	-1.03	-0.24	0.45	1.10	2.48	-0.80	-0.08	0.51	1.18	2.67
	6 - 21	-0.97	0.26	1.06	1.77	3.78	-0.74	0.29	1.07	1.82	3.81	-0.44	0.46	1.21	1.94	3.88
	22 - 31	-0.93	0.13	0.86	1.55	3.46	-0.75	0.22	0.89	1.61	3.47	-0.33	0.42	1.06	1.82	3.57
Feb	1 - 4	-1.20	0.22	0.83	1.89	3.40	-0.95	0.29	0.91	1.91	3.32	-0.63	0.57	1.08	2.10	3.47
	5 - 13	-1.17	-0.27	0.41	1.13	3.49	-1.03	-0.20	0.44	1.16	3.43	-0.66	0.01	0.59	1.31	3.31
	14 - 29	-1.28	0.14	0.81	1.70	3.44	-1.16	0.27	0.87	1.76	3.43	-0.78	0.43	1.01	1.90	3.62
Mar	1 - 31	-1.47	-0.24	0.63	1.33	3.25	-1.31	-0.13	0.65	1.34	3.20	-0.93	0.02	0.75	1.40	3.38
Apr	1 - 30	-1.42	-0.10	0.71	1.43	2.95	-1.27	-0.06	0.70	1.41	2.90	-1.01	0.05	0.77	1.47	2.92
May	1 - 20	-1.20	0.19	1.02	1.82	3.67	-1.05	0.27	1.08	1.78	3.62	-0.73	0.41	1.15	1.86	3.77
	22 - 31	-1.21	0.12	1.03	1.73	3.70	-1.13	0.18	1.02	1.77	3.71	-0.90	0.20	1.04	1.74	3.74
Jun	5 - 25	-1.15	0.28	1.12	1.95	3.80	-0.28	0.49	1.07	1.52	3.20	-0.43	0.50	1.08	1.53	3.43
Jul	1 - 31	-1.08	0.30	1.21	2.05	4.11	0.54	1.20	1.47	1.85	3.37	0.55	1.23	1.51	1.89	3.49
Aug	1 - 31	-1.43	0.25	1.16	2.09	3.93	0.73	1.32	1.62	2.07	3.19	0.78	1.36	1.68	2.10	3.35
Sep	1 - 30	-1.38	0.00	0.93	1.93	3.67	0.98	1.45	1.73	2.05	3.09	1.03	1.48	1.74	2.08	3.26
Oct	1 - 15	-1.66	-0.27	0.70	1.71	3.30	0.65	1.13	1.40	1.64	2.77	0.74	1.20	1.47	1.73	2.94
	17 - 31	-1.68	-0.12	0.79	1.72	3.56	0.77	1.20	1.41	1.71	2.86	0.86	1.27	1.47	1.78	2.98
Nov	12 - 19	-1.31	-0.13	0.47	1.31	3.23	-1.18	-0.10	0.51	1.34	3.18	-0.86	0.04	0.57	1.45	3.34
	20 - 30	-1.40	-0.11	0.83	1.67	3.50	-1.24	-0.05	0.87	1.66	3.52	-1.03	0.10	0.88	1.69	3.56
Dec	1 - 31	-1.28	0.09	0.94	1.76	4.31	-1.16	0.17	0.97	1.75	4.25	-0.91	0.26	1.02	1.79	4.43

Table B-1 (cont.). Distribution of stages (feet) by study period in 2008: historical barrier configurations

		MIDDB					RMID027					MHR				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-1.08	-0.28	0.40	1.18	2.56	-1.06	-0.26	0.45	1.16	2.59	-0.94	-0.12	0.49	1.15	2.58
	6 - 21	-0.82	0.39	1.29	1.95	3.83	-0.84	0.39	1.26	1.97	3.83	-0.53	0.53	1.31	1.99	3.80
	22 - 31	-0.86	0.36	1.05	1.85	3.50	-0.81	0.38	1.05	1.85	3.48	-0.50	0.49	1.16	1.91	3.51
Feb	1 - 4	-1.01	0.62	1.24	2.01	3.73	-1.02	0.62	1.26	2.04	3.74	-0.68	0.74	1.26	2.08	3.85
	5 - 13	-1.11	-0.05	0.70	1.41	3.37	-1.06	-0.03	0.67	1.41	3.42	-0.82	0.11	0.81	1.43	3.44
	14 - 29	-1.17	0.38	1.12	1.94	3.54	-1.12	0.40	1.14	1.96	3.56	-0.97	0.49	1.18	1.97	3.53
Mar	1 - 31	-1.41	-0.14	0.72	1.50	3.25	-1.37	-0.12	0.72	1.46	3.26	-1.29	-0.03	0.75	1.42	3.24
Apr	1 - 30	-1.44	0.00	0.79	1.49	3.12	-1.44	0.01	0.80	1.49	3.12	-1.23	0.08	0.83	1.47	2.98
May	1 - 20	-1.11	0.26	1.05	1.80	3.62	-1.15	0.24	1.04	1.80	3.65	-1.10	0.28	1.06	1.75	3.65
	22 - 31	-1.16	0.17	1.12	1.85	3.66	-0.43	0.45	1.10	1.65	3.56	-0.49	0.41	1.04	1.61	3.63
Jun	5 - 25	-1.14	0.28	1.18	1.99	3.90	-0.49	0.52	1.15	1.70	3.65	-0.56	0.47	1.12	1.66	3.71
Jul	1 - 31	-0.90	0.49	1.37	2.24	4.21	0.77	1.25	1.55	2.11	4.08	0.73	1.22	1.51	2.08	4.07
Aug	1 - 31	-1.10	0.44	1.37	2.28	4.00	0.95	1.32	1.60	2.19	3.79	0.95	1.30	1.58	2.15	3.76
Sep	1 - 30	-1.05	0.22	1.19	2.10	3.82	1.12	1.32	1.55	2.05	3.65	1.11	1.32	1.56	2.04	3.65
Oct	1 - 15	-1.42	-0.10	0.90	1.76	3.39	0.98	1.23	1.41	1.70	3.27	0.97	1.22	1.40	1.74	3.28
	17 - 31	-1.42	0.02	1.00	1.85	3.72	1.05	1.25	1.42	1.82	3.55	1.05	1.24	1.42	1.78	3.45
Nov	12 - 19	-1.22	0.09	0.86	1.60	3.43	-1.20	0.06	0.85	1.62	3.44	-1.02	0.15	0.82	1.59	3.40
	20 - 30	-1.34	0.05	0.97	1.75	3.55	-1.28	0.06	0.96	1.71	3.56	-1.16	0.16	0.98	1.68	3.53
Dec	1 - 31	-1.22	0.20	1.02	1.85	4.33	-1.18	0.19	1.02	1.83	4.35	-1.10	0.25	1.04	1.78	4.31

		RMID040					ROLD074					RSAN087 (SANUB)				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-0.47	0.19	0.69	1.30	2.70	0.04	0.65	1.09	1.58	2.70	0.25	0.84	1.22	1.68	2.73
	6 - 21	-0.16	0.85	1.48	2.11	3.90	0.57	1.44	1.91	2.47	3.88	0.85	1.67	2.08	2.61	3.91
	22 - 31	0.07	0.98	1.48	2.17	3.53	0.80	2.10	2.49	2.98	4.04	1.06	2.49	2.94	3.32	4.31
Feb	1 - 4	0.10	0.97	1.54	2.36	3.84	1.45	1.97	2.31	2.99	4.12	1.89	2.37	2.63	3.23	4.30
	5 - 13	-0.05	0.49	1.00	1.66	3.52	0.95	1.50	1.85	2.31	3.56	1.32	1.88	2.19	2.62	3.70
	14 - 29	-0.36	0.80	1.33	2.16	3.63	0.64	1.55	1.99	2.70	3.64	1.02	1.86	2.29	2.92	3.71
Mar	1 - 31	-0.67	0.26	0.93	1.53	3.36	0.45	1.11	1.61	2.03	3.38	0.78	1.42	1.83	2.22	3.41
Apr	1 - 30	-0.66	0.34	0.99	1.59	3.08	0.29	1.23	1.72	2.12	3.25	0.62	1.56	1.96	2.33	3.38
May	1 - 20	-0.60	0.60	1.27	1.92	3.77	0.93	1.77	2.22	2.62	3.96	1.40	2.15	2.53	2.90	4.11
	22 - 31	-0.59	0.36	1.04	1.76	3.69	0.20	1.13	1.70	2.28	3.82	0.48	1.40	1.87	2.39	3.85
Jun	5 - 25	-0.65	0.40	1.03	1.66	3.58	-0.03	0.97	1.51	2.02	3.55	0.12	1.10	1.59	2.07	3.57
Jul	1 - 31	0.71	1.20	1.50	1.98	3.73	0.80	1.49	1.77	2.16	3.52	0.83	1.54	1.83	2.23	3.54
Aug	1 - 31	0.96	1.33	1.64	2.13	3.55	1.03	1.59	1.89	2.29	3.36	1.05	1.62	1.95	2.33	3.38
Sep	1 - 30	1.13	1.39	1.64	2.06	3.36	1.21	1.64	1.87	2.19	3.19	1.22	1.66	1.91	2.23	3.21
Oct	1 - 15	0.96	1.24	1.44	1.76	3.09	1.03	1.43	1.64	1.91	2.96	1.06	1.48	1.70	1.97	2.98
	17 - 31	1.02	1.26	1.45	1.77	3.21	1.08	1.39	1.58	1.85	3.11	1.13	1.60	1.94	2.31	3.60
Nov	12 - 19	-0.58	0.24	0.82	1.58	3.35	0.06	0.75	1.18	1.82	3.26	0.28	0.93	1.31	1.91	3.26
	20 - 30	-0.79	0.30	1.06	1.73	3.52	-0.11	0.85	1.43	1.99	3.48	0.11	1.07	1.56	2.05	3.50
Dec	1 - 31	-0.67	0.44	1.11	1.86	4.37	-0.11	0.95	1.48	2.11	4.34	0.11	1.13	1.61	2.16	4.35

Table B-2. Distribution of flows (cfs) by study period in 2008: historical barrier configurations

		ROLD040					ROLD047					ROLD059				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-7700	-4859	-883	2733	4869	-1838	-1151	306	1236	2115	-484	-330	289	450	658
	6 - 21	-14349	-7658	-3688	2038	5454	-2101	-1075	293	1505	2697	-511	-243	320	558	906
	22 - 31	-15652	-7653	-4060	1273	6634	-1920	-937	411	1476	2642	-425	-132	426	635	993
Feb	1 - 4	-14919	-9093	-6496	2382	4500	-1686	-872	155	1544	2101	-349	-110	323	631	888
	5 - 13	-15121	-8529	-4345	541	5458	-2259	-888	234	1315	2465	-583	-168	359	548	907
	14 - 29	-17716	-8121	-4680	1557	5461	-2156	-958	238	1440	2396	-510	-186	297	585	936
Mar	1 - 31	-13791	-6321	-2623	3517	6250	-2292	-1180	373	1347	1915	-611	-278	355	528	680
Apr	1 - 30	-14951	-6062	-284	4475	6204	-2578	-1206	369	1345	1803	-682	-285	356	532	678
May	1 - 20	-12939	-5428	613	5019	6956	-2636	-1422	371	1409	2051	-642	-313	402	600	786
	22 - 31	-11020	-6181	-667	3877	6459	-2169	-1309	279	1245	2272	-625	-328	296	516	831
Jun	5 - 25	-11114	-5293	-973	2944	5163	-1417	-538	35	510	860	-228	-38	59	255	554
Jul	1 - 31	-16947	-7039	-5083	-838	2541	-1604	-372	272	624	1008	-237	139	297	374	515
Aug	1 - 31	-17029	-6632	-4811	-1032	4313	-1409	-322	372	666	939	-197	138	323	400	559
Sep	1 - 30	-14953	-6498	-4796	-985	2211	-1205	-224	7	518	817	-308	-66	142	356	522
Oct	1 - 15	-11759	-6065	-3968	-500	1821	-1026	-202	477	699	855	-132	180	340	431	529
	17 - 31	-11088	-6010	-3625	-145	1936	-1219	-227	438	684	883	-249	81	348	430	534
Nov	12 - 19	-13877	-8749	-5468	256	4360	-2367	-1033	23	1220	2297	-635	-296	181	468	697
	20 - 30	-12680	-7155	-3015	3114	6224	-2448	-1435	498	1476	1950	-666	-387	327	500	650
Dec	1 - 31	-13385	-6454	-1530	3728	6679	-2703	-1339	365	1424	2168	-758	-372	270	496	742

		MID at VICT					RMID027					RMID040				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-6587	-4332	214	2981	4892	-946	-537	220	571	1060	-18	13	39	60	126
	6 - 21	-8682	-5846	-1687	3093	5752	-1134	-654	125	724	1475	-104	3	53	91	193
	22 - 31	-9269	-5422	-1670	2439	5743	-1098	-564	174	694	1416	-87	40	87	135	235
Feb	1 - 4	-8682	-6160	-3321	3072	5183	-1037	-537	87	721	1227	-77	14	74	120	203
	5 - 13	-8953	-6062	-1711	2042	5291	-1194	-573	84	632	1433	-49	26	71	94	194
	14 - 29	-10317	-5813	-2516	2570	5630	-1231	-610	131	709	1444	-131	11	63	105	191
Mar	1 - 31	-8754	-4997	-768	3541	5671	-1305	-644	69	625	1018	-41	40	68	93	184
Apr	1 - 30	-9552	-5122	125	4131	5555	-1363	-619	99	623	933	-65	40	74	105	189
May	1 - 20	-9316	-5078	735	4354	6154	-1224	-733	133	633	1048	27	70	108	144	250
	22 - 31	-7062	-4996	-610	3344	5791	-1175	-403	100	364	853	20	48	81	115	209
Jun	5 - 25	-7389	-4925	-397	3279	5248	-1348	-537	46	374	860	-57	48	70	97	163
Jul	1 - 31	-10685	-5908	-2240	1793	4571	-1386	-513	49	249	802	-210	20	57	87	176
Aug	1 - 31	-10365	-5681	-2159	1842	5017	-1310	-471	91	284	799	-198	12	64	98	162
Sep	1 - 30	-9430	-5804	-1827	2308	4568	-1219	-376	124	287	748	-184	16	70	96	154
Oct	1 - 15	-7192	-5381	-1664	2096	4410	-1078	-228	83	199	666	-148	22	53	74	137
	17 - 31	-7546	-5663	-1472	2400	4310	-1201	-250	91	216	738	-192	-15	54	80	151
Nov	12 - 19	-9666	-6122	-2626	2266	4958	-1369	-660	-45	565	1139	-119	-6	23	62	163
	20 - 30	-8902	-5893	-576	3703	5779	-1352	-664	101	660	985	-94	17	47	81	186
Dec	1 - 31	-9773	-5335	-580	3796	6247	-1565	-682	79	653	1108	-145	19	51	86	237

Table B-2 (cont.). Distribution of flows (cfs) by study period in 2008: historical barrier configurations

		GRL009					ORP					ROLD074				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-2871	-1694	1692	2810	4190	-84	420	828	1286	1661	-153	704	933	1113	1557
	6 - 21	-3304	-1195	1538	3356	4949	-252	885	1225	1597	1976	-198	1047	1235	1489	2168
	22 - 31	-2999	-287	2096	3690	5533	21	1475	1838	2337	2812	-127	1547	2060	2304	3018
Feb	1 - 4	-2216	-126	1667	3612	4497	1112	1526	1899	2089	2356	1060	1701	1908	2080	2532
	5 - 13	-3330	-290	1882	3317	5268	373	1381	1769	1878	2278	676	1477	1680	1917	2472
	14 - 29	-3378	-553	1612	3408	4891	170	1097	1528	1814	2234	-110	1291	1516	1752	2654
Mar	1 - 31	-3580	-1306	1768	3185	3923	168	856	1326	1594	1958	74	1141	1313	1544	2078
Apr	1 - 30	-3949	-1187	1912	3154	3776	316	924	1399	1592	2063	93	1114	1382	1671	2337
May	1 - 20	-3461	-1406	2180	3349	4260	839	1148	1657	1951	2227	885	1520	1723	1893	2567
	22 - 31	-3461	-1615	1569	2922	4491	-88	699	1150	1465	2095	-36	968	1186	1453	2033
Jun	5 - 25	-4167	-2370	868	2699	4307	-525	158	690	1101	1506	-548	600	752	942	1472
Jul	1 - 31	-2854	-689	231	850	2127	-126	309	507	686	1174	-278	154	452	1058	1676
Aug	1 - 31	-2582	-579	69	654	1833	-143	160	388	621	1229	-345	5	289	1002	1633
Sep	1 - 30	-2251	-429	157	726	1776	-482	-15	268	583	1247	-563	-145	121	904	1574
Oct	1 - 15	-1938	-388	18	481	1392	-197	84	334	612	985	-354	-26	263	919	1514
	17 - 31	-2339	-484	56	504	1648	-17	168	271	368	652	-135	155	324	537	785
Nov	12 - 19	-3990	-1326	819	2923	4363	-588	498	980	1292	1661	-617	779	938	1206	1513
	20 - 30	-3972	-2165	1644	3070	3716	-593	290	959	1313	1590	-690	656	920	1235	1729
Dec	1 - 31	-4566	-1994	1412	3020	4317	-934	288	960	1302	1718	-968	702	928	1142	1786

		VICT					ROLD034					RSAN072				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-2249	-1214	778	2381	3538	-8623	-5667	-312	3813	6379	-1665	-624	1035	1554	1980
	6 - 21	-2687	-966	1664	3489	6320	-12941	-7805	-3225	3288	7447	-2112	-924	938	1894	2385
	22 - 31	-2940	-505	1776	3489	6895	-14021	-7113	-3116	2206	7831	-2007	651	1801	2364	2940
Feb	1 - 4	-2149	-1104	2973	4160	6564	-13253	-9051	-5576	4095	6572	-1517	382	1547	2347	2608
	5 - 13	-2467	-213	1993	3773	6749	-13639	-8284	-3758	1636	6899	-1825	-13	1470	2043	2530
	14 - 29	-2544	-728	2062	3642	7952	-15558	-7872	-4002	2491	7332	-2192	-525	1232	2065	2424
Mar	1 - 31	-2817	-1576	1220	2788	6189	-12900	-6586	-2075	4497	7730	-1968	-323	1203	1888	2299
Apr	1 - 30	-2781	-2004	226	2742	6705	-13874	-6582	-58	5468	7548	-2079	-198	1305	1896	2418
May	1 - 20	-3133	-2208	-89	2598	6031	-13080	-6388	789	5874	8390	-1731	473	1736	2208	2699
	22 - 31	-2968	-1744	681	2892	4767	-9957	-6475	-880	4409	7871	-1995	-683	1144	1746	2447
Jun	5 - 25	-2359	-1489	615	2597	4541	-9301	-6088	-612	4093	6974	-2430	-1241	482	1570	2205
Jul	1 - 31	-1585	-36	2383	3388	7963	-15550	-7482	-4303	1031	5205	-2838	-1271	304	1506	2170
Aug	1 - 31	-2051	10	2072	3285	7745	-15265	-7288	-3839	1151	6052	-2656	-1135	536	1633	2163
Sep	1 - 30	-1452	-85	2017	3328	6966	-14072	-7480	-3525	1611	5103	-2390	-949	744	1709	2155
Oct	1 - 15	-1301	-157	1620	3121	5508	-10768	-7041	-2998	1611	4837	-2130	-681	930	1686	2092
	17 - 31	-1179	-331	1647	3242	5111	-10220	-7194	-2935	2144	4541	-2052	-482	1134	1781	2228
Nov	12 - 19	-2139	-117	2291	3845	6042	-13359	-8687	-5046	1992	6285	-2572	-1322	372	1499	2106
	20 - 30	-2762	-1444	1158	3283	5837	-12187	-7736	-1300	4478	7759	-2351	-1136	695	1639	2252
Dec	1 - 31	-3101	-1705	664	2990	6097	-12829	-7183	-1270	4761	8326	-2680	-1070	743	1719	2542

Table B-3. Distribution of stages (feet) by study period in 2008: without-barriers condition

		GRL009					GRLUB					DGL				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-0.78	-0.05	0.54	1.24	2.61	-0.74	-0.04	0.55	1.23	2.63	-0.75	-0.01	0.60	1.24	2.67
	6 - 21	-0.50	0.54	1.28	1.97	3.88	-0.47	0.55	1.28	1.98	3.88	-0.43	0.59	1.29	2.01	3.90
	22 - 31	-0.33	0.47	1.09	1.82	3.52	-0.29	0.52	1.09	1.85	3.52	-0.29	0.57	1.17	1.91	3.53
Feb	1 - 4	-0.53	0.57	1.12	2.08	3.34	-0.47	0.60	1.15	2.12	3.38	-0.40	0.67	1.23	2.16	3.46
	5 - 13	-0.56	0.06	0.63	1.34	3.40	-0.50	0.10	0.66	1.34	3.39	-0.46	0.12	0.72	1.37	3.38
	14 - 29	-0.73	0.44	1.02	1.95	3.56	-0.70	0.48	1.04	1.97	3.57	-0.69	0.50	1.06	2.00	3.62
Mar	1 - 31	-0.96	0.05	0.82	1.45	3.29	-0.93	0.07	0.84	1.46	3.31	-0.90	0.12	0.85	1.49	3.36
Apr	1 - 30	-0.95	0.14	0.84	1.56	3.03	-0.90	0.17	0.88	1.57	3.03	-0.85	0.19	0.92	1.60	3.05
May	1 - 20	-0.75	0.50	1.24	1.90	3.70	-0.72	0.50	1.25	1.93	3.70	-0.69	0.54	1.26	1.95	3.77
	22 - 31	-0.80	0.32	1.12	1.86	3.77	-0.80	0.34	1.15	1.86	3.78	-0.81	0.35	1.17	1.89	3.79
Jun	5 - 25	-0.82	0.44	1.17	1.89	3.78	-0.79	0.42	1.19	1.88	3.77	-0.75	0.46	1.21	1.91	3.75
Jul	1 - 31	-0.56	0.59	1.26	1.93	3.91	-0.53	0.60	1.27	1.94	3.90	-0.51	0.62	1.28	1.95	3.94
Aug	1 - 31	-0.78	0.58	1.24	2.01	3.71	-0.76	0.58	1.26	2.00	3.71	-0.73	0.59	1.28	2.02	3.70
Sep	1 - 30	-0.68	0.38	1.11	1.84	3.55	-0.66	0.40	1.13	1.83	3.54	-0.63	0.44	1.14	1.85	3.53
Oct	1 - 15	-1.06	0.10	0.92	1.55	3.17	-1.02	0.14	0.94	1.56	3.16	-0.98	0.15	0.94	1.59	3.18
	17 - 31	-1.01	0.25	0.95	1.64	3.47	-0.97	0.26	0.97	1.64	3.47	-0.93	0.28	0.97	1.67	3.48
Nov	12 - 19	-0.85	0.04	0.64	1.38	3.30	-0.80	0.05	0.66	1.39	3.31	-0.79	0.08	0.66	1.44	3.33
	20 - 30	-1.03	0.14	0.97	1.78	3.55	-1.00	0.17	0.99	1.79	3.54	-0.98	0.19	1.02	1.78	3.54
Dec	1 - 31	-0.89	0.31	1.04	1.86	4.36	-0.85	0.32	1.05	1.87	4.37	-0.83	0.36	1.07	1.87	4.40

		ROLD046					ROLD047					ROLD059				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-1.12	-0.33	0.36	1.10	2.54	-1.03	-0.24	0.45	1.10	2.48	-0.80	-0.08	0.51	1.18	2.67
	6 - 21	-0.97	0.26	1.06	1.77	3.78	-0.74	0.29	1.07	1.82	3.81	-0.44	0.46	1.21	1.94	3.88
	22 - 31	-0.93	0.13	0.86	1.55	3.46	-0.75	0.22	0.89	1.61	3.47	-0.33	0.42	1.06	1.82	3.57
Feb	1 - 4	-1.20	0.22	0.83	1.89	3.40	-0.95	0.29	0.91	1.91	3.32	-0.63	0.57	1.08	2.10	3.47
	5 - 13	-1.17	-0.27	0.41	1.13	3.49	-1.03	-0.20	0.44	1.16	3.43	-0.66	0.01	0.59	1.31	3.31
	14 - 29	-1.28	0.14	0.81	1.70	3.44	-1.16	0.27	0.87	1.76	3.43	-0.78	0.43	1.01	1.90	3.62
Mar	1 - 31	-1.47	-0.24	0.63	1.33	3.25	-1.31	-0.13	0.65	1.34	3.20	-0.93	0.02	0.75	1.40	3.38
Apr	1 - 30	-1.42	-0.10	0.71	1.43	2.95	-1.27	-0.06	0.70	1.41	2.90	-1.01	0.05	0.77	1.47	2.92
May	1 - 20	-1.20	0.19	1.02	1.82	3.67	-1.05	0.27	1.08	1.78	3.62	-0.73	0.41	1.15	1.86	3.77
	22 - 31	-1.21	0.13	1.03	1.73	3.71	-1.13	0.18	1.01	1.79	3.72	-0.90	0.19	1.04	1.75	3.75
Jun	5 - 25	-1.11	0.27	1.12	1.90	3.80	-1.01	0.31	1.12	1.86	3.79	-0.87	0.34	1.08	1.86	3.75
Jul	1 - 31	-0.90	0.39	1.11	1.89	3.96	-0.78	0.43	1.15	1.84	3.93	-0.63	0.46	1.19	1.89	3.99
Aug	1 - 31	-1.22	0.37	1.12	1.93	3.71	-1.03	0.41	1.12	1.92	3.68	-0.81	0.47	1.18	1.96	3.76
Sep	1 - 30	-1.09	0.16	0.91	1.77	3.52	-0.89	0.22	0.96	1.76	3.53	-0.67	0.32	1.03	1.82	3.54
Oct	1 - 15	-1.45	-0.16	0.67	1.44	3.16	-1.30	-0.09	0.74	1.46	3.15	-1.09	0.04	0.82	1.53	3.23
	17 - 31	-1.45	0.01	0.78	1.53	3.38	-1.23	0.09	0.85	1.55	3.38	-1.00	0.18	0.90	1.64	3.47
Nov	12 - 19	-1.31	-0.20	0.45	1.28	3.23	-1.18	-0.12	0.50	1.31	3.18	-0.86	-0.02	0.57	1.44	3.34
	20 - 30	-1.40	-0.11	0.86	1.68	3.50	-1.24	-0.05	0.87	1.68	3.52	-1.03	0.10	0.88	1.71	3.56
Dec	1 - 31	-1.28	0.09	0.94	1.76	4.31	-1.16	0.17	0.97	1.75	4.25	-0.91	0.26	1.02	1.79	4.43

Table B-3 (cont.). Distribution of stage (feet) by study period in 2008: without-barriers condition

		MIDDB					RMID027					MHR				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-1.08	-0.28	0.40	1.18	2.56	-1.06	-0.26	0.45	1.16	2.59	-0.94	-0.12	0.49	1.15	2.58
	6 - 21	-0.82	0.39	1.29	1.95	3.83	-0.84	0.39	1.26	1.97	3.83	-0.53	0.53	1.31	1.99	3.80
	22 - 31	-0.86	0.36	1.05	1.85	3.50	-0.81	0.38	1.05	1.85	3.48	-0.50	0.49	1.16	1.91	3.51
Feb	1 - 4	-1.01	0.62	1.24	2.01	3.73	-1.02	0.62	1.26	2.04	3.74	-0.68	0.74	1.26	2.08	3.85
	5 - 13	-1.11	-0.05	0.70	1.41	3.37	-1.06	-0.03	0.67	1.41	3.42	-0.82	0.11	0.81	1.43	3.44
	14 - 29	-1.17	0.38	1.12	1.94	3.54	-1.12	0.40	1.14	1.96	3.56	-0.97	0.49	1.18	1.97	3.53
Mar	1 - 31	-1.41	-0.14	0.72	1.50	3.25	-1.37	-0.12	0.72	1.46	3.26	-1.29	-0.03	0.75	1.42	3.24
Apr	1 - 30	-1.44	0.00	0.79	1.49	3.12	-1.44	0.01	0.80	1.49	3.12	-1.23	0.08	0.83	1.47	2.98
May	1 - 20	-1.11	0.26	1.05	1.80	3.62	-1.15	0.24	1.04	1.80	3.65	-1.10	0.28	1.06	1.75	3.65
	22 - 31	-1.16	0.16	1.13	1.86	3.66	-1.12	0.19	1.11	1.83	3.65	-1.14	0.21	1.03	1.78	3.67
Jun	5 - 25	-1.11	0.31	1.19	1.92	3.84	-1.11	0.33	1.18	1.92	3.82	-1.04	0.31	1.09	1.86	3.76
Jul	1 - 31	-0.77	0.60	1.40	2.15	4.08	-0.77	0.58	1.39	2.14	4.05	-0.68	0.59	1.31	2.09	4.08
Aug	1 - 31	-0.99	0.56	1.37	2.18	3.87	-1.03	0.56	1.38	2.17	3.86	-0.87	0.60	1.34	2.11	3.80
Sep	1 - 30	-0.89	0.36	1.23	2.00	3.69	-0.91	0.36	1.20	1.96	3.68	-0.72	0.45	1.20	1.94	3.62
Oct	1 - 15	-1.30	0.03	0.92	1.67	3.26	-1.29	0.05	0.95	1.65	3.26	-1.14	0.10	0.90	1.61	3.28
	17 - 31	-1.28	0.14	1.01	1.73	3.60	-1.30	0.17	0.99	1.76	3.60	-1.06	0.24	0.98	1.73	3.52
Nov	12 - 19	-1.22	0.02	0.85	1.55	3.43	-1.19	0.05	0.84	1.55	3.44	-1.02	0.13	0.80	1.57	3.40
	20 - 30	-1.34	0.05	0.99	1.77	3.55	-1.28	0.06	0.96	1.72	3.56	-1.16	0.16	0.98	1.70	3.53
Dec	1 - 31	-1.22	0.20	1.02	1.85	4.33	-1.18	0.19	1.02	1.83	4.35	-1.10	0.25	1.04	1.78	4.31

		RMID040					ROLD074					RSAN087 (SANUB)				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-0.47	0.19	0.69	1.30	2.70	0.04	0.65	1.09	1.58	2.70	0.25	0.84	1.22	1.68	2.73
	6 - 21	-0.16	0.85	1.48	2.11	3.90	0.57	1.44	1.91	2.47	3.88	0.85	1.67	2.08	2.61	3.91
	22 - 31	0.07	0.98	1.48	2.17	3.53	0.80	2.10	2.49	2.98	4.04	1.06	2.49	2.94	3.32	4.31
Feb	1 - 4	0.10	0.97	1.54	2.36	3.84	1.45	1.97	2.31	2.99	4.12	1.89	2.37	2.63	3.23	4.30
	5 - 13	-0.05	0.49	1.00	1.66	3.52	0.95	1.50	1.85	2.31	3.56	1.32	1.88	2.19	2.62	3.70
	14 - 29	-0.36	0.80	1.33	2.16	3.63	0.64	1.55	1.99	2.70	3.64	1.02	1.86	2.29	2.92	3.71
Mar	1 - 31	-0.67	0.26	0.93	1.53	3.36	0.45	1.11	1.61	2.03	3.38	0.78	1.42	1.83	2.22	3.41
Apr	1 - 30	-0.66	0.34	0.99	1.59	3.08	0.29	1.23	1.72	2.12	3.25	0.62	1.56	1.96	2.33	3.38
May	1 - 20	-0.60	0.60	1.27	1.92	3.77	0.93	1.77	2.22	2.62	3.96	1.40	2.15	2.53	2.90	4.11
	22 - 31	-0.81	0.29	1.12	1.82	3.77	0.19	1.12	1.70	2.27	3.82	0.48	1.39	1.87	2.39	3.86
Jun	5 - 25	-0.87	0.28	1.08	1.82	3.68	-0.10	0.94	1.54	2.05	3.70	0.06	1.09	1.62	2.10	3.71
Jul	1 - 31	-0.52	0.58	1.27	1.97	3.90	0.16	1.07	1.59	2.15	3.86	0.31	1.19	1.67	2.21	3.87
Aug	1 - 31	-0.63	0.64	1.33	2.09	3.67	0.03	1.07	1.60	2.21	3.64	0.20	1.19	1.69	2.26	3.66
Sep	1 - 30	-0.48	0.53	1.22	1.90	3.50	0.15	0.96	1.48	2.03	3.41	0.32	1.10	1.56	2.09	3.41
Oct	1 - 15	-0.84	0.28	0.96	1.61	3.16	-0.29	0.74	1.28	1.73	3.16	-0.08	0.91	1.40	1.79	3.18
	17 - 31	-0.76	0.39	1.08	1.74	3.49	-0.08	0.87	1.40	1.87	3.41	0.15	1.04	1.50	1.94	3.43
Nov	12 - 19	-0.58	0.23	0.82	1.54	3.35	0.06	0.73	1.16	1.81	3.26	0.28	0.92	1.30	1.91	3.26
	20 - 30	-0.79	0.30	1.06	1.74	3.52	-0.11	0.85	1.43	1.99	3.48	0.11	1.07	1.56	2.05	3.50
Dec	1 - 31	-0.67	0.44	1.11	1.86	4.37	-0.11	0.95	1.48	2.11	4.34	0.11	1.13	1.61	2.16	4.35

Table B-4. Distribution of flows (cfs) by study period in 2008: without-barriers condition

		ROLD040					ROLD047					ROLD059				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-7700	-4859	-883	2733	4869	-1838	-1151	306	1236	2115	-484	-330	289	450	658
	6 - 21	-14349	-7658	-3688	2038	5454	-2101	-1075	293	1505	2697	-511	-243	320	558	906
	22 - 31	-15652	-7653	-4060	1273	6634	-1920	-937	411	1476	2642	-425	-132	426	635	993
Feb	1 - 4	-14919	-9093	-6496	2382	4500	-1686	-872	155	1544	2101	-349	-110	323	631	888
	5 - 13	-15121	-8529	-4345	541	5458	-2259	-888	234	1315	2465	-583	-168	359	548	907
	14 - 29	-17716	-8121	-4680	1557	5461	-2156	-958	238	1440	2396	-510	-186	297	585	936
Mar	1 - 31	-13791	-6321	-2623	3517	6250	-2292	-1180	373	1347	1915	-611	-278	355	528	680
Apr	1 - 30	-14951	-6062	-284	4475	6204	-2578	-1206	369	1345	1803	-682	-285	356	532	678
May	1 - 20	-12939	-5428	613	5019	6956	-2636	-1422	371	1409	2051	-642	-313	402	600	786
	22 - 31	-11039	-6162	-694	3900	6472	-2183	-1301	237	1243	2273	-624	-327	288	516	832
Jun	5 - 25	-11241	-6200	-715	3853	6363	-2433	-1568	104	1241	2277	-726	-405	227	490	750
Jul	1 - 31	-17064	-8728	-4831	711	4664	-2670	-1310	-79	1248	2457	-822	-320	174	504	827
Aug	1 - 31	-18035	-8312	-4399	915	5866	-2582	-1335	28	1282	2301	-715	-325	206	510	764
Sep	1 - 30	-15305	-8418	-3890	1201	4422	-2244	-1309	82	1393	2238	-625	-325	244	509	721
Oct	1 - 15	-12518	-7760	-3167	1656	4099	-2056	-1231	193	1333	2069	-530	-291	202	478	696
	17 - 31	-12219	-7799	-2864	2211	4475	-2047	-1260	110	1402	2132	-532	-333	234	490	691
Nov	12 - 19	-13877	-8739	-5468	257	4360	-2367	-1033	23	1220	2297	-635	-296	181	468	697
	20 - 30	-12680	-7155	-3015	3114	6224	-2448	-1435	498	1476	1950	-666	-387	327	500	650
Dec	1 - 31	-13385	-6454	-1530	3728	6679	-2703	-1339	365	1424	2168	-758	-372	270	496	742

		MID at VICT					RMID027					RMID040				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-6587	-4332	214	2981	4892	-946	-537	220	571	1060	-18	13	39	60	126
	6 - 21	-8682	-5846	-1687	3093	5752	-1134	-654	125	724	1475	-104	3	53	91	193
	22 - 31	-9269	-5422	-1670	2439	5743	-1098	-564	174	694	1416	-87	40	87	135	235
Feb	1 - 4	-8682	-6160	-3321	3072	5183	-1037	-537	87	721	1227	-77	14	74	120	203
	5 - 13	-8953	-6062	-1711	2042	5291	-1194	-573	84	632	1433	-49	26	71	94	194
	14 - 29	-10317	-5813	-2516	2570	5630	-1231	-610	131	709	1444	-131	11	63	105	191
Mar	1 - 31	-8754	-4997	-768	3541	5671	-1305	-644	69	625	1018	-41	40	68	93	184
Apr	1 - 30	-9552	-5122	125	4131	5555	-1363	-619	99	623	933	-65	40	74	105	189
May	1 - 20	-9316	-5078	735	4354	6154	-1224	-733	133	633	1048	27	70	108	144	250
	22 - 31	-7206	-5118	-468	3399	5851	-1200	-694	13	554	1143	2	48	77	110	221
Jun	5 - 25	-7851	-5358	-365	3543	5871	-1337	-791	-11	555	1162	-73	39	68	101	213
Jul	1 - 31	-10833	-6306	-2473	2245	5178	-1352	-782	-96	588	1239	-155	18	46	93	198
Aug	1 - 31	-10599	-6100	-2068	2585	5361	-1306	-780	-24	647	1149	-172	3	37	83	185
Sep	1 - 30	-9717	-6211	-1809	2834	4940	-1223	-752	34	689	1137	-151	-6	35	73	154
Oct	1 - 15	-8086	-5746	-1388	2880	4806	-1148	-666	38	616	1034	-116	8	40	68	149
	17 - 31	-8416	-5907	-1722	3226	5014	-1185	-726	33	633	1082	-124	10	44	74	172
Nov	12 - 19	-9665	-6122	-2625	2267	4958	-1369	-661	-45	565	1139	-119	-6	23	62	163
	20 - 30	-8902	-5893	-576	3703	5779	-1352	-664	101	660	985	-94	17	47	81	186
Dec	1 - 31	-9773	-5335	-580	3796	6247	-1565	-682	79	653	1108	-145	19	51	86	237

Table B-4 (cont.). Distribution of flows (cfs) by study period in 2008: without-barriers condition

		GRL009					ORP					ROLD074				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-2871	-1694	1692	2810	4190	-84	420	828	1286	1661	-153	704	933	1113	1557
	6 - 21	-3304	-1195	1538	3356	4949	-252	885	1225	1597	1976	-198	1047	1235	1489	2168
	22 - 31	-2999	-287	2096	3690	5533	21	1475	1838	2337	2812	-127	1547	2060	2304	3018
Feb	1 - 4	-2216	-126	1667	3612	4497	1112	1526	1899	2089	2356	1060	1701	1908	2080	2532
	5 - 13	-3330	-290	1882	3317	5268	373	1381	1769	1878	2278	676	1477	1680	1917	2472
	14 - 29	-3378	-553	1612	3408	4891	170	1097	1528	1814	2234	-110	1291	1516	1752	2654
Mar	1 - 31	-3580	-1306	1768	3185	3923	168	856	1326	1594	1958	74	1141	1313	1544	2078
Apr	1 - 30	-3949	-1187	1912	3154	3776	316	924	1399	1592	2063	93	1114	1382	1671	2337
May	1 - 20	-3461	-1406	2180	3349	4260	839	1148	1657	1951	2227	885	1520	1723	1893	2567
	22 - 31	-3458	-1596	1596	2906	4485	-8	700	1137	1434	2076	-76	969	1187	1463	2039
Jun	5 - 25	-4066	-2430	1040	2762	4389	-913	72	685	1188	1731	-867	551	818	1032	1512
Jul	1 - 31	-4677	-2091	504	2778	4681	-924	228	693	1205	1783	-1094	570	850	1050	1666
Aug	1 - 31	-4436	-2091	693	2879	4272	-835	133	748	1221	1668	-905	562	823	1006	1624
Sep	1 - 30	-3832	-2116	916	2974	4231	-896	105	746	1202	1607	-963	515	804	1006	1618
Oct	1 - 15	-3377	-1898	861	2909	3961	-606	301	787	1233	1520	-720	575	824	1052	1529
	17 - 31	-3451	-1990	966	2980	4252	-497	319	785	1239	1668	-596	628	873	1108	1462
Nov	12 - 19	-3990	-1325	818	2923	4363	-588	498	979	1292	1661	-617	779	938	1206	1513
	20 - 30	-3972	-2165	1644	3070	3716	-593	290	959	1313	1590	-690	656	920	1235	1729
Dec	1 - 31	-4566	-1994	1412	3020	4317	-934	288	960	1302	1718	-968	702	928	1142	1786

		VICT					ROLD034					RSAN072				
		Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max	Min	0.25	Med	0.75	Max
Jan	1 - 5	-2249	-1214	778	2381	3538	-8623	-5667	-312	3813	6379	-1665	-624	1035	1554	1980
	6 - 21	-2687	-966	1664	3489	6320	-12941	-7805	-3225	3288	7447	-2112	-924	938	1894	2385
	22 - 31	-2940	-505	1776	3489	6895	-14021	-7113	-3116	2206	7831	-2007	651	1801	2364	2940
Feb	1 - 4	-2149	-1104	2973	4160	6564	-13253	-9051	-5576	4095	6572	-1517	382	1547	2347	2608
	5 - 13	-2467	-213	1993	3773	6749	-13639	-8284	-3758	1636	6899	-1825	-13	1470	2043	2530
	14 - 29	-2544	-728	2062	3642	7952	-15558	-7872	-4002	2491	7332	-2192	-525	1232	2065	2424
Mar	1 - 31	-2817	-1576	1220	2788	6189	-12900	-6586	-2075	4497	7730	-1968	-323	1203	1888	2299
Apr	1 - 30	-2781	-2004	226	2742	6705	-13874	-6582	-58	5468	7548	-2079	-198	1305	1896	2418
May	1 - 20	-3133	-2208	-89	2598	6031	-13080	-6388	789	5874	8390	-1731	473	1736	2208	2699
	22 - 31	-2921	-1694	568	2805	4745	-10041	-6563	-867	4537	7926	-1996	-689	1148	1748	2449
Jun	5 - 25	-2836	-1709	581	2854	4770	-10098	-6892	-953	4696	7975	-2415	-1267	488	1619	2305
Jul	1 - 31	-2251	-414	2192	3921	8143	-15984	-8683	-3979	1971	6717	-2915	-1547	15	1502	2197
Aug	1 - 31	-2607	-485	2070	3729	8289	-15557	-8180	-3381	2564	7151	-2801	-1522	134	1557	2171
Sep	1 - 30	-2025	-662	1778	3751	7028	-14419	-8332	-3031	2856	6263	-2570	-1489	225	1604	2039
Oct	1 - 15	-1874	-765	1672	3510	5664	-11361	-7820	-2822	3167	6085	-2286	-1291	365	1545	1997
	17 - 31	-2117	-1003	1268	3588	5399	-11249	-8021	-2182	3460	6368	-2405	-1300	558	1594	2150
Nov	12 - 19	-2139	-117	2291	3845	6040	-13358	-8683	-5039	1992	6285	-2572	-1322	373	1499	2106
	20 - 30	-2762	-1444	1158	3283	5837	-12187	-7736	-1300	4478	7759	-2351	-1136	695	1639	2252
Dec	1 - 31	-3101	-1705	664	2990	6097	-12829	-7183	-1270	4761	8326	-2680	-1070	743	1719	2542